A CLASSIFICATION OF THE LEPIDOPTERA BASED ON CHARACTERS OF THE PUPA

BY

EDNA MOSHER

B. S. A., Cornell University, 1908

M. S., University of Illinois, 1913

THESIS

Submitted in Partial Fulfilment of the Requirements for the

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DOCTOR OF PHILOSOPHY

IN ENTOMOLOGY

IN

THE GRADUATE SCHOOL

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INTRODUCTION

It is within comparatively recent times that the immature stages of insects have been considered of any taxonomic value. The economic entomologist early realized the value of being able to recognize the immature stages, for in many orders of insects the larval stages alone were responsible for many ravages upon crops and orchards. Still the matter was not taken up by the systematists, and the workers in the field of economic entomology contented themselves by rearing the adult to determine the species, and then describing, perhaps all the stages, or more probably the larval and adult stages as being those of economic importance. Nowadays we are beginning to see that it is impossible to construct an adequate classification of any group of insects unless we use every bit of information obtainable on their life history and habits.

It is possible to multiply instances of the value of the larval stages in classification, so that one scarcely needs to cite examples; but the pupae have been less frequently used. There are cases, however, in which the only good taxonomic characters available are found in the pupal stage of the insect. Such instances are found among the nematocerous Diptera, particularly in the family Chironomidae. Scudder ('89) was the first to attempt a classification of lepidopterous pupae, but his keys to the chrysalids were based, not on structural characters, but on the various projections from the body, the cuticular appendages, the coloration, and the mode of suspension.

Among the Lepidoptera a great deal of work has been done towards the classification of the larvae, but until 1893 nothing of importance had been done towards a study of the pupae. In this year Dr. T. A. Chapman, in a paper entitled "Some Neglected Points in the Pupae of Heterocerous Lepidoptera," called attention to the fact that the pupae possessed some remarkable taxonomic characters which might be used to clear up many of the disputed points in the classification

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of the order. This he endeavored to do for the groups in which material was available for study, and he has since published other articles as additional material was obtained. However, Dr. Chapman attempted no classification of the Lepidoptera on this basis, merely pointing out the pupal characters of the major groups and calling attention to instances in which a study of these characters would apparently alter the existing schemes of classification.

The attention of American entomologists was called to this subject by Dr. A. S. Packard ('95) in a paper entitled "Attempt at a New Classification of the Lepidoptera." He made a new grouping of the order based upon pupal characters and figured a large number of species. His determinations of the homology of the various parts of the pupae studied were far from correct, and this, of course, invalidated many of his conclusions.

Since that time nothing has been done in America towards a classification of the Lepidoptera based on pupal characters. The purpose of the present investigation is to present such a classification as far as material has been available for study. There is also an attempt to throw some light on the relationships existing between the different groups.

Changes Preceding Pupation

The person who begins the study of pupae with the preconceived notion that the pupal stage is an interpolated one in the insect's life and that a pupa bears little or no resemblance to either larva or adult, will probably find abundant cause for a change of mind before his study is completed. In the case of Lepidoptera one is apt to think that no similarities could possibly exist between any of the three stages of the insect's development after it leaves the egg. After careful study, however, one is surprised with the resemblance between the stages, for it is of the highest importance in the study of any group to be able to homologize larval, pupal, and imaginal characters. This has been done to some extent in certain orders of insects, particularly in those groups where the resemblance between the larva and adult is more striking than in the case of the Lepidoptera. Attempts have been made, however, even in this order, to homologize the mouth-parts of the larva and adult, and some of the larval structures have been homologized with certain structures in the pupa; but apparently the idea that all three stages should be studied has been left for other minds to entertain.

The first striking difference between larva and pupa is that of size. This difference is easily explained by the great difference in the size of the alimentary canal. Another striking difference is that the

pupa apparently lacks legs and prolegs. As will be shown later, the legs are always present, but folded and not in use, while the scars of all the prolegs remain to show their location and are very easily identified in the majority of cases. Many lepidopterous larvae possess striking tubercles and warts, and usually an abundance of setae. All larvae possess setae, but they are often inconspicuous. On the exposed portions of the body surface, in so far as observed, the pupa always retains the scars of these warts and tubercles, and the pupal body possesses setae arranged in most cases in the exact order in which they occurred in the larva. Many other structures of the larva can be easily identified in the pupa, and these will be discussed later.

In the case of insects with complete metamorphosis the name pupa is applied to the stage of the insect in which it is more or less quiescent while undergoing the changes which are necessary to fit it for its adult life. This word pupa, from the Latin meaning baby, was applied to this stage by Linnaeus from the resemblance of certain pupae to a baby which has been swathed or bound up, as was the custom in many parts of Europe at that time. This name was perhaps more appropriate for the pupae of the Lepidoptera than for those of any other order of insects because the appendages are usually all soldered to the thorax.

The change from larva to pupa in the Lepidoptera has been observed by many workers and is full of surprises for the amateur who wishes to breed these insects. The caterpillar when ready to pupate stops feeding, and in many instances leaves the food plant and wanders about, often apparently in the greatest of haste. Many are then seen on sidewalks, garden paths, and other traveled places, especially during the autumn months, when the majority of larvae are seeking a place to spend the winter. These larvae, if confined, will refuse food and many of them spin silk threads which are used to suspend the pupa or to form a cocoon. The alimentary canal is always freed of any food materials. The larval skin at this time loses its luster and becomes more and more wrinkled; and the body becomes shorter and shorter and appears swollen, which is due to the molting-fluid glands pouring their secretions between the outer and inner layers of cuticle. Some drops of a yellowish or reddish fluid are usually found in the place where larvae are confined and this, together with their peculiar appearance, often leads the amateur breeder of Lepidoptera to think that decomposition is taking place, and results in the hasty disposal of the now helpless insect. In the case of larvae which spin a cocoon these changes are not so easily observed, unless the cocoon is a very frail one, because most of the changes described take place inside of the cocoon. These changes may occupy but a few

hours, or may last for nearly a week. In the case of the common tomato-worm, *Protoparce carolina,* the transformation process usually requires five days; certain species of Papilio observed took but three days, but the time varies much with different individuals and the conditions under which they live.

When the molting fluid has done its work in loosening the larval cuticle, this splits along the meson of the thorax, and is gradually worked to the caudal end of the body, liberating the enclosed pupa. The liberated pupa is covered with a more or less transparent cuticle and resembles the pupa of the more generalized Neuroptera, Trichoptera, and Coleoptera. In all of these orders, the insects on casting their larval skins show the first resemblance to the adult insect. In the Neuroptera, Trichoptera, and Coleoptera, the appendages, as well as the body, are encased in a pupal skin, are free from each other and the body, and together with the body segments possess considerable freedom of motion. This does not mean that the pupae have any power of locomotion; on the contrary they are quite helpless, and for this reason are frequently—in common with the great majority of pupae—protected by some sort of a cocoon, or earthen cell. The lepidopterous genus Micropteryx, which is supposed by many to be the most generalized of its order, retains freedom of motion in all the appendages and in all but the fixed caudal segments of the abdomen. This freedom of motion is gradually lost in lepidopterous pupae as specialization advances, and the adult appendages are not fully developed when the pupal stage is assumed, although the cases of the appendages of the pupa are fully formed. Specialization in the pupa consists also in the hardening of the exposed parts of the cuticle through the deposition of chitin, and in the soldering of the appendages to each other and to the body of the pupa. In the generalized families the appendages are soldered to each other but often remain free from the body surface; later the wings become attached to the body surface, but any parts of the antennae, legs, or maxillae extending beyond their caudal margins remain free. The tips of these appendages are provided for in various ways in the higher families, but are always found soldered firmly to the surface of the body of the pupa. Proceeding hand in hand with the soldering down of the appendages is the loss of motion in the abdominal segments. Among certain families there is motion between all of the adjacent segments. There is, however, a successive loss of motion between segments, until the conjunctiva between all but two of the segments is inflexible in some forms, and even in some of the Lepidoptera, entire freedom of motion has been lost in all of the segments.

Among generalized forms where the appendages are soldered together, the cuticle of the exposed parts of the body contains but very little chitin, and is but slightly differentiated in texture from the cuticle of the hidden surfaces. When the imago emerges, or even before that time if the body is slightly pressed, the appendages separate very readily from each other, and are not torn upon the emergence of the insect, so that the pupal skin often remains complete except for the slit on the dorso-meson through which the imago emerged. A very different condition exists, however, among highly specialized forms. Here the exposed portions of cuticle become very hard and firm, while those which are not exposed are very thin and delicate and are almost entirely destroyed at the emergence of the imago. The outer covering, of course, being so firmly soldered together, remains in one piece and is apparently complete except for the slit through which the insect emerged. This has led many to think that this outer chitinized portion was the entire pupal skin and that it was a structure, analogous perhaps to an egg shell, in which the pupa had been enclosed.

Another remarkable difference between the generalized and the highly specialized Lepidoptera lies in the fact that in the latter the appendages are not fully formed when pupation takes place, but consist of the transparent cuticular coverings through which one or more slender tracheae may be seen. The duration of the pupal stage doubtless influences this, there being a stronger tendency among highly specialized forms to hibernate as pupae.

During the life of the pupa the adult parts are developing, and before it is time for the imago to emerge, the cuticular parts of the adult are fully formed. In the generalized families previously mentioned and in some specialized forms where the pupal cuticle remains more or less transparent, one is able to see a part of the development taking place, especially in the case of the appendages. The scales appear on the legs and wings and the color pattern may often be easily traced on the latter several days before the emergence of the insect. This stage of the insect, after the cuticular parts are fully formed, and while it still retains its pupal skin, has been designated as the preimago*. If the pupal skin is not already dark in color, it grows considerably darker in the last few days before the insect emerges, and one is thus able to determine when the preimago stage is reached.

*Packard applied the term subimago to the corresponding stage in certain Hymenoptera. This is an unfortunate use of the term as subimago had already been applied to the first winged stage of the Ephemeridae.

External Morphology

The most important work on pupal morphology has been done by E. B. Poulton and Dr. T. A. Chapman. Poulton ('91) in his paper on the "External Morphology of the Lepidopterous Pupa" discusses a few pupal structures but does not attempt to name all of the parts or to locate any of them. So far as known he was the first to point out that the pupal structures were more than cases for the imaginal structures and objected to the terms pterothecae, ophthalmothecae, etc., as applied to pupae. Believing that Poulton's theory is correct, such terms have not been used in this discussion, nor the terms wing cases, antennal cases, leg cases, etc., but these are spoken of simply as wings, antennae, maxillae, etc. Chapman's papers, already referred to, discuss very fully some of the structures and describe their exact location; but as they include only a few figures one is left very much in doubt as to the identity of many of the structures and their location. W. Hatchett Jackson ('91) published a very valuable paper on the "Morphology of the Lepidoptera" in which he discussed the external determination of sex in the pupa. A short discussion of the chrysalis was published by Dr. S. H. Scudder ('89), and some of the parts were named. In a paper previously cited, Dr. A. S. Packard ('95) gives many figures of pupae and names the parts, but his homologies are far from correct. It seems necessary, therefore, before proceeding further, to discuss the principal pupal structures and indicate their location by means of figures.

The homologies given in this paper were determined by a series of dissections of pupae in various stages of development, the preimago being found most valuable for this purpose. Pupae of nearly every family mentioned in this discussion have been studied in this way, beginning with the Micropterygoidea and extending through the Hepialoidea, Cossoidea, and other generalized families, including the Saturnioidea which are believed to be the most specialized of lepidopterous pupae. The change from larva to pupa has been watched in many species and the subsequent folding and soldering down of the appendages carefully noted. A large number of species have been bred and a study of the method of dehiscence, as shown by the pupal skin, has thrown considerable light on many instances where there was doubt as to the number of free abdominal segments, or where a suture was obscured by folds or other modifications of the integument.

The three regions of the body—head, thorax, and abdomen—are easily recognized, and each will be discussed in turn. There occur, on all of the regions of the body, in different families prominent pro-

jections and ridges of various types especially in the Papilionoidea. These projections have no morphological significance.

THE HEAD

The usual sclerites found in the head of generalized insects may be located in lepidopterous pupae. The sutures are distinct in generalized pupae, but are obliterated in the more specialized groups.

Vertex.—This is an area found on the dorsum of the head. It reaches its highest development in the Gracilarioidea, but is usually distinct in all generalized pupae. It is bounded cephalad by the Y-shaped epicranial suture (es), and may be seen in Figures 3, 25, 29, 33, 49, 53, and 56; v. This area was referred to by Chapman and Packard as the dorsal head-piece.

Front.—The front is the sclerite to which the antennae are attached. It is bounded by the epicranial suture on the dorsal surface, and on the ventral surface by the fronto-clypeal suture, which normally extends for a short distance caudad from the base of each antenna and then transversely to the median line. In some pupae where there is a "shoving back" of the head parts as in the Pyraustidae (Fig. 76) and Sphingidae, the front is located on the dorsum of the head. The fronto-clypeal suture is usually not distinct except in very generalized forms. The superfamily Gelechioidea, however, shows it very distinctly. It is indicated in Figures 1, 8, 26, 30, and 36; f. In generalized pupae the front bears two setae on each side of the meson which are often very conspicuous.

Genae.—These sclerites are distinctly bounded in Eriocraniidae and Hepialidae (Figs. 1 and 8, g). They are found laterad of the front and clypeus, and mesad of the glazed eye. The mandibles are always adjacent to the genae at their lateral margins.

Clypeus.—Remarkably few pupae have the clypeus definitely bounded. The suture between the clypeus and labrum is seldom present, although it is often indicated by a furrow. It is then impossible to determine accurately as to its presence, but it has been considered as if it were present. The boundaries of the clypeus are shown very distinctly in Figure 1, cl. In the Hepialidae (Fig. 8) there is no clypeo-labral suture present although all the other head sutures are distinct. The clypeus can usually be identified by the presence of the invaginations for the anterior arms of the tentorium, which are associated with its lateral margins. This sclerite often bears prominent setae, and in the pupae of species whose larvae are borers it has often a distinct cutting plate or ridge.

Tentorium.—The invaginations for the anterior arms of the tentorium are very distinct and are either small pores or slit-like openings. They are associated with the lateral margins of the clypeus and are distinct in most pupae (Figs. 1, 14, 19, 30; at).

Labrum.—The labrum is usually distinct along its lateral and distal margins, but seldom separated from the clypeus by a distinct suture. Like the clypeus it usually bears setae which are especially conspicuous in the Eriocraniidae (Figs. 1 and 2, lb). A peculiar development occurs in the Heliozelidae and some other families where the labrum extends caudad over the appendages (Fig. 50).

Pilifers.—This term is applied to the caudo-lateral projections of the labrum, which are so well developed in many Lepidoptera. They are very large in certain superfamilies, notably the Pyralidoidea and the Papilionoidea, and their presence is easily detected by the lobes which are adjacent to the caudo-lateral angles of the labrum and often approximate, or meet on the meson caudad of it, or are separated by a narrow piece of the labial palpi (Figs. 70, 72, 74, 76, 78, 79; pf). The mandibles figured by Scudder ('89, Vol. 3, Pl. 87, Fig. 25) are the pilifers. There are often well-developed pilifers present, however, when there are no external indications of their presence.

Mandibles.—The mandibles are always located adjacent to the caudo-lateral angles of the labrum. They are not functional except in the Micropterygoidea. In this superfamily, as shown in a pupa of the Eriocraniidae (Fig. 1, md), the mandibles are very large and used by the pupa to cut its way out of its cocoon and in working its way to the surface of the ground. In the Hepialidae (Fig. 8, md) and in some other families (Fig. 11, md) the mandibular area is definitely bounded. In still other families the area is distinctly elevated and usually rugose, as in the Eucleidae and Aegeriidae (Figs. 19 and 36, md). This type of mandibular area is observed in many of the Sphingidae. In the majority of pupae, however, the mandibles are represented by a smooth area situated in the position indicated above.

Eye-pieces.—These are situated laterad of the genae and mesad of the antennae. There are always two regions to be noted: a smooth mesal portion, sometimes only a narrow band but often a wider lunate piece, called the glazed eye-piece; and the larger lateral portion, the sculptured eye-piece. The latter is so called because it is always sculptured like the adjacent parts of the thorax. The sculpturing on the head is seldom like that found on the thorax and abdomen, but, strange to say, that on the sculptured eye-piece is always like that on the thorax, although the eye-piece is probably an extension of the vertex. On the dehiscence of most generalized pupae the eye-pieces are

separated from the face-parts and remain attached to the conjunctiva which joins the vertex to the prothorax (Fig. 43). In the specialized forms they remain attached to the face-parts. A peculiar modification is found in the Eucleoidea (Figs. 17, 19, 23; se, ge) in which the eye-pieces form movable flaps seemingly to protect and to cover the meso-thoracic spiracles which lie underneath. The glazed eye-piece probably represents the pupal eye.

Antennae.—These are always attached to the front and extend laterad, curving to the ventral surface of the body mesad of the meso-thoracic wings. They may always be identified without any trouble (Figs. 1, 8, 11, 15, 28; a). In pupae with broadly pectinate antennae, as the Saturniidae, the mesal portion is frequently elevated and has been referred to as the "stem of the flagellum" of the antennae.

Labial Palpi.—These appendages lie adjacent on the meson caudad of the labrum except in the Eriocraniidae (Fig. 1, lp). They are visible in the majority of pupae (Figs. 8, 15, 28, 45, 61). They are frequently overlaid and concealed by the maxillae at their proximal end as in Figures 61 and 67, lp. Often they are entirely concealed by the maxillae with the exception of a small V-shaped piece just caudad of the labrum (Fig. 72). This was thought by Scudder to be a special piece for covering the base of the tongue.

Maxillae.—Where labial palpi are visible they occupy a mesal position, caudad of the labrum, with the maxillae laterad of them. When they are invisible and apparently absent, the maxillae lie adjacent on the meson, often overlying and concealing the proximal ends of the labial palpi as mentioned above. The maxillae (Figs. 1, 8, 17, 24, 28; mx) vary greatly in length but are never entirely lacking or concealed in the pupa. They often extend beyond the caudal margin of the wings, being sometimes free and sometimes soldered to other appendages. The greatest development is found in certain of the Sphingidae where the maxillae do not extend beyond the caudal margin of the wings, but the extra length is taken up in a loop at the proximal end which forms the so-called "jug handle" of Sphinx pupae. The maxillae are always measured on the meson from the caudal margin of the labrum to their distal end and are usually compared in length with the wings, which are measured from the caudal margin of the labrum to their caudal margin on the meson.

Maxillary Palpi.—Each palpus is represented on each side by a subrectangular or triangular area caudad of the eye-pieces and lying along the cephalic margins of the prothoracic and mesothoracic legs, frequently reaching as far mesad as the proximo-lateral angle of each maxilla. The normal position of these appendages is discussed under

the family Eriocraniidae and shown in part in Figure 1, mp. They may also be seen in Figures 28, 30, 32, 36, 38; mp. Structures which may be maxillary palpi are found in the genus Gracilaria (Fig. 47). The peculiar extensions of the maxillae in the Cossoidea and Eucleoidea are not considered as maxillary palpi (Figs. 15, 19, 23).

THE THORAX

The three segments of the thorax are always distinct. They are only visible on the dorsum, because the ventral and lateral surfaces are covered by the appendages.

Prothorax.—This segment probably varies more in size and shape than any of the others. There are some forms, as in the Gracilarioidea, Yponomeutoidea, and others, where the prothorax is very short on the meson (Figs. 53, 56, 58; p) or even invisible (Fig. 54), but is very wide at each lateral margin. It is longer in the Galleridae and certain families of Noctuoidea than in any other pupae examined.

Prothoracic Legs.—These lie adjacent to the maxillae at their proximal end. The coxae are frequently exposed, especially in generalized pupae where the appendages are free (Figs. 1, 11, 19; cx1), and dissection frequently showed a segment cephalad of the coxa, the trochantin, although there was no distinct suture indicated on the exterior, this being covered by the mouth-parts. The trochanter is a very small segment usually found at the caudal end of the femur when the leg is folded and is therefore generally concealed by the tibia and tarsus. The femur extends from the trochanter cephalad to the caudal margin of the head. It is frequently concealed by the tibia and tarsus which are the only portions of the prothoracic leg always visible, but they are often shoved slightly laterad so that a portion of the femur is exposed (Figs. 1, 8, 24, 32, 36; f1). The tibia and tarsus are seldom divided by a suture except in generalized pupae, where all the segments, even of the tarsi, are readily distinguished (Fig. 1, l_1).

Mesothorax.—The mesothorax is usually considerably longer than the other segments in specialized forms, but in generalized pupae all the segments are more nearly equal.

Mesothoracic Spiracle.—This is usually located on the dorsum between the prothorax and mesothorax, sunk deep in the conjunctiva between the segments with an opening adjacent to the caudo-lateral angles of the prothorax. Its primitive position appears to have been much farther ventrad (Fig. 2, msp) and it is found in this position in the specialized Trichoptera. It retains this primitive position in the superfamily Eucleoidea and in the family Nepticulidae. The caudal margin possesses curious modifications in different families in

the way of elevated ridges, tubercles, setae, etc., and in some of the Papilionoidea, particularly in the families Hesperiidae and Lycaenidae, there seems to be a definite external closing apparatus in many of the genera. Sometimes there is a tuft of setae; in others, a plug or plate of somewhat honeycombed appearance.

Mesothoracic Legs.—These are folded in exactly the same manner as the prothoracic legs and the femora are very seldom exposed, but may be seen in Figure 1, f2. The coxae are frequently visible (Figs. 1 and 48, cx2). The mesothoracic legs are usually longer than those of the prothorax. The tibia and tarsus of each leg are always exposed (Figs. 1, 8, 23, 30; l_2). They lie on the venter, between the prothoracic legs and the antennae.

Mesothoracic Wings.—The wings of the mesothorax almost conceal those of the metathorax, except in the most generalized forms where the appendages are free. In most families they are the only wings visible on the ventral surface (Figs. 1, 8, 36, 41; w1).

Tegulae.—The tegulae are the large lobes which, in the adult, cover the proximal end of the wing. They do not form separate pupal pieces but are indicated in some pupae (Fig. 2, t). The tegulae are referred to by many authors as the patagia. The patagia are lobes of the pronotum which project over the mesonotum.

Alar Furrows.—The furrows along each lateral margin of the mesonotum are designated as the alar furrows. They are best developed in the Aegerioidea (Fig. 37, af) although there are distinct depressions in many families.

Axillary Tubercles.—In the genera Tropaea and Telea of the Saturniidae, there is found a large tubercle at the base of each wing, with sometimes an additional smaller one. The edges of these tubercles are strongly chitinized and somewhat roughened, and serve to cut the cocoon for the emergence of the moth. They are probably assisted in this by the peculiar development of the wing sclerites of the preimago, which protrude into these tubercles and are sometimes found to have cut the pupal skin at the apex of the tubercle.

Metathorax.—This segment is longest in generalized forms, where its length is nearly equal to that of the mesothorax.

Metathoracic Legs.—The tibiae and tarsi of the metathoracic legs are never normally exposed for their entire length but are concealed by the other appendages excepting at their distal end. Only a small portion is visible in specialized pupae, and the appendages are often wholly concealed (Figs. 2, 8, 36, 45; l_3).

Metathoracic Wings.—These are usually covered by the mesothoracic wings except for a narrow strip along their dorsal margin.

In a few families a narrow strip of the metathoracic wings is visible on the ventral surface caudad of the mesothoracic wings (Figs. 1, 8, 19; w2).

THE ABDOMEN

The abdomen consists of ten segments, of which three, segments 8–10, are always "fixed"; that is, they possess no power of independent motion. In the generalized forms motion is possible between all of the other segments. A segment is said to be movable when there is movement between its caudal margin and the segment caudad of it. In many pupae the movable segments are capable of being telescoped so that only their caudal margins are visible. When the cephalic margin of a movable segment is referred to, it includes the rounded part of the segment which is covered by the transverse conjunctiva when the segments are retracted, or telescoped.

Proleg Scars.—The scars of the larval prolegs are found on the ventral surface near the meson (Fig. 11, psc) and are often conspicuous.

Tubercle Scars.—Those families in which the larvae have prominent tubercles show very definite scars in the pupae. These are especially noticeable in the Saturniidae.

Setae.—There are usually setae present on the abdomen, and they are arranged much as are those of the larvae. They are often very inconspicuous, otherwise they might furnish good taxonomic characters. There is often a dense covering of secondary setae over the entire surface, as in some gelechiids and lasiocampids. The Pterophoridae retain a spiny armature similar to that found in the larvae.

Spines.—These are found covering the dorsum of the abdomen in generalized pupae (Fig. 49), and larger ones are also found at the caudal end of the body (Figs. 27, 31). They are arranged in rows on the segments in Tineoidea and Tortricoidea (Figs. 27, 31, 39, 41).

Flanged Plates.—The flanged plates are best developed in the pupae of borers, but are found in other pupae as well. Figure 9 shows them well developed on the dorsum and also shows a well-developed ventral plate on the seventh segment. They are usually developed along the cephalic margin of the segment and prevent the telescoping of the segments.

Genital Openings.—In the male the genital opening is situated on the ventro-meson of the ninth abdominal segment. It is usually either a mere slit-like opening as in Figure 5, without any adjacent elevations, or it has a distinctly elevated tubercle on each side as in Figure 8, go, and occasionally is situated in a slight depression. In the females there are two openings which may or may not become con-

fluent. These may be mere rounded pores or slit-like openings, and are associated apparently with the eighth and ninth segments. The boundary lines between segments 8 and 9, and 9 and 10 are rarely distinct on the meson, and where they are distinct it seems as if the caudal opening were associated with the tenth segment. In the more specialized pupae the caudal margins of the eighth and ninth segments are more strongly curved cephalad near the meson than in the male (Figs. 34 and 44, go) and the segments are dovetailed together. The presence of the two openings apparently represents the more generalized condition (Figs. 7, 17, 28; go). They are confluent in *Podosesia syringae* (Fig. 36) and *Archips argyrospila* (Fig. 44).

Anal Opening.—This is always situated on the meson near the caudal margin of the tenth segment. It sometimes shows as a circular opening (Fig. 7, ao) but is usually slit-like (Figs. 8, 14, 17). It is usually surrounded on each side with several prominent wrinkles or folds.

Anal Rise.—The anal opening is frequently situated on the summit of a mound-like elevation known as the anal rise. The setae on this rise are very conspicuous in certain families of Tortricoidea (Fig. 38, ar).

Abdominal Spiracles.—Spiracles are always present on abdominal segments 1–8. The spiracles of the first segment are covered, so far as observed, by the wings, except in the superfamily Eucleoidea and the family Nepticulidae. The spiracles of the eighth segment are never functional and show no distinct opening.

Spiracular Furrows.—On the cephalic margin of the movable segments cephalad of the spiracles are found furrows which frequently extend almost to the meson on both dorsal and ventral aspects. They occur in several families, as the Liparidae and Geometridae, but are best developed in the Sphingidae, where they are lacking in but a few genera. They are usually separated by sharply carinate ridges and are of various types, but their function is unknown.

Cremaster.—The cremaster is a prolongation of the tenth segment and is not found in the more generalized pupae. It was homologized by C. V. Riley with the suranal plate of the larva. It is of various lengths and shapes and often bears setae at the distal end. Two types of cremaster are shown in Figures 41 and 65, cr. Its length is measured on the ventral surface from its junction with the curve of the ventral surface of the body, as in Figure 44, where ab represents the cremastral length.

Classification

As no extensive classification of the Lepidoptera based on pupal characters has been attempted hitherto, little has been done to determine what characters are of value in defining superfamilies, families, and genera. It has been necessary, therefore, to base specific, generic, and other distinctions on those characters found in such material as could be secured. The present investigation has been limited by the difficulty in obtaining representatives of many groups, and it is not expected that the tables and descriptions given will do more than furnish a basis for later work upon the subject. It is hoped, however, that they will call the attention of entomologists to the vast possibilities opened up by the use of the taxonomic characters available in pupae, and that further studies of the different groups will make it possible to identify an insect in one more stage of its life cycle—which can not fail to be of importance in the case of our economic species.

Analytical Table of Superfamilies

a. Mandibles present, large, functional, decussating, and extending beyond the lateral margins of the body. MICROPTERYGOIDEA.

aa. Mandibles, if present, never large, parallel or subparallel, and usually represented by small elevated tubercles.

b. Movable abdominal segments present cephalad of the fourth, or if no segments are movable cephalad of the fourth then the appendages free from each other and never soldered to the body wall, and the vertex longer than the prothorax measured on the meson.

c. True maxillary palpi never present, but sometimes lateral extensions of the maxillae (Figs. 15 and 19).

d. Body heavily chitinized and bearing transverse rows of spines or setae on the abdominal segments; spiracles never visible on the first abdominal segment.

e. Mesothorax never more than twice the length of the metathorax; seventh abdominal segment with a large flanged plate on the ventral surface; antennae filiform, short, only reaching caudad to the proximal end of the mesothoracic legs; head sutures all present except the clypeo-labral. HEPIALOIDEA.

ee. Mesothorax always more than twice the length of the metathorax; seventh abdominal segment never with a large

flanged plate on the ventral surface; antennae, if present, pectinate and reaching farther caudad than the proximal end of the mesothoracic legs; none of the head sutures distinct for the whole length.

COSSOIDEA.

dd. Body never heavily chitinized, and never bearing the spines or setae on the abdominal segments in rows; spiracles always visible on the first abdominal segment.

EUCLEOIDEA.

cc. True maxillary palpi usually present; if absent, then the appendages free from each other, or the vertex longer than the prothorax on the meson, or the body possessing a distinct cremaster.

d. Dorsum of abdomen with a covering of small spines, usually over the entire length of the segment and not arranged in distinct rows; if spines are arranged in rows then the maxillary palpi are absent; vertex always longer than the prothorax on the meson.

GRACILARIOIDEA.

dd. Dorsum of the abdomen with a distinct row of spines along the cephalic margin of the segment, with or without a caudal row; spines seldom found elsewhere on the segment but, if present, then the maxillary palpi present and well developed.

e. Caudal row of spines never present on the dorsum of the abdominal segments; maxillary palpi always present.

TINEOIDEA

ee. Caudal row of spines always present on the dorsum of the abdominal segments; maxillary palpi usually present.

f. Distinct cremaster never present; setae never present on the anal rise; wings narrow and pointed; large spines always present on the venter of the tenth abdominal segment.

AEGERIOIDEA.

ff. Distinct cremaster usually present, if not, then setae present on the anal rise; wings broad and never pointed; large spines never present on the venter of the tenth abdominal segment.

TORTRICOIDEA.

bb. Movable abdominal segments never present cephalad of the fourth; appendages never free from each other and usually soldered to the body wall.

c. Lobes indicating the presence of pilifers always present except in Gallerinae (Fig. 69) and Oeneinae (Fig. 80).

d. Maxillary palpi usually present, if absent, then abdominal segment seven is movable in the male, the body covered with a spiny armature, and both prothoracic and mesothoracic legs extending cephalad between the eye-pieces and the antennae, the former reaching nearly to the cephalic margin of the glazed eye, or a deep furrow lined with setae present on the dorsum between the ninth and tenth abdominal segments; antennae never clubbed at the distal end; femora of the prothoracic legs usually visible; labial palpi very seldom visible except as a small triangular or polygonal area caudad of the labrum and between the pilifers. PYRALIDOIDEA.

dd. Maxillary palpi never present; antennae always clubbed at the distal end; femora of the prothoracic legs never visible; a deep furrow lined with setae never present on the dorsum between the ninth and tenth abdominal segments; labial palpi never visible except as small triangular or polygonal areas caudad of the labrum between the pilifers and often entirely concealed. PAPILIONOIDEA.

cc. Lobes indicating the presence of pilifers never present.

d. Mesothoracic wings on the ventral surface at meson usually extending considerably beyond the caudal margin of the fourth abdominal segment, if not, then the body depressed, mostly in the thoracic region, the incisions between the movable segments very deep on the dorsum and venter and less deep at the lateral margins, and the caudal part of the antennae always adjacent on the meson for a considerable distance; abdominal segments 1–4 usually longer than the other segments; epicranial suture always present.

e. Maxillary and labial palpi present and well developed and a large portion of the prothoracic femora always exposed; if maxillary palpi are not present then the fronto-clypeal suture never visible; prothorax distinctly shorter on the meson than at each side, so that each half is triangular in outline; appendages soldered to each other but not to the body wall; fronto-clypeal suture never visible; antennae with the caudal portion very rarely touching and not moniliform in appearance. YPONOMEUTOIDEA.

ee. Maxillary palpi usually present, but labial palpi and prothoracic femora seldom visible, if visible, then the fronto-clypeal suture distinct; prothorax usually the same length

on the meson as at each side so that each half is subquadrangular in outline; appendages usually soldered firmly to each other and to the body wall; body usually ovate in outline, broadest in the thoracic region and usually strongly depressed; fronto-clypeal suture usually visible; antennae usually moniliform in appearance, the caudal portion always adjacent on the meson, usually for some distance; if only touching, then the fronto-clypeal suture is distinct.

GELECHIOIDEA.

dd. Mesothoracic wings on the ventral surface of the body at meson rarely extending beyond the caudal margin of the fourth abdominal segment, if beyond, then maxillary palpi never present; abdominal segments 1–4 or 1–6 rarely longer than the other segments; epicranial suture seldom visible.

e. Labial palpi usually present and well developed and from one fourth to one fifth the length of the wings, if not visible then the body usually shaped as in Figure 104; the abdomen with setae arranged around the scars of larval verrucae, and usually flanged plates on the abdomen and a cremaster present; or with a more or less dense covering of setae never arranged around larval verrucae, the body never of the shape in Figure 104 and flanged plates never present on the abdomen nor a distinct cremaster.

f. Labial palpi usually present and well developed and the prothoracic femora usually exposed, or if not, then both prothoracic and mesothoracic legs reaching cephalad to the eye-pieces; if both labial palpi and prothoracic femora are wanting then the body of the type in Figure 104; the abdomen with setae arranged around the scars of larval verrucae, flanged plates usually present on the abdominal segments and a distinct cremaster often present; body never with a more or less dense covering of setae, except arranged as mentioned above; maxillary palpi occasionally present.

NOCTUOIDEA.

ff. Labial palpi sometimes present, body never with a cremaster and always with a more or less dense covering of setae which are never arranged around larval verrucae; prothoracic femora never exposed; maxillary palpi never present.

BOMBYCOIDEA.

ee. Labial palpi never visible, unless represented by small triangular or polygonal areas caudad of the labrum; body very seldom with visible setae.

f. Suture adjacent to the proximal ends of the antennae and separating the clypeus and front always present and very distinct; antennae never broadly pectinate so that the width is one fifth of the length; spiracular furrows often present.

g. Antennae usually considerably broader near the proximal end, their greatest width usually greater than that of the prothoracic legs; antennae usually more than three fourths the length of the wings, if not, then the epicranial suture is present, or the cremaster is wanting, or if present, bifurcate at the distal end or bearing hooked setae; dorsum of the abdomen usually with a deep furrow between the ninth and tenth segments; scar of a caudal horn never present on the dorsum of the eighth abdominal segment; labial palpi sometimes visible as small triangular or polygonal areas caudad of the labrum. NOTODONTOIDEA.

gg. Antennae rarely very much broader near the proximal end, usually filiform, their greatest width seldom greater than that of the prothoracic legs, if greater then the cremaster is never wanting, nor bifurcate, nor with hooked setae; antennae never more than three fourths the length of the wings; epicranial suture never present; dorsum of the abdomen never with a deep furrow between the ninth and tenth segments; scar of a caudal horn usually present on the dorsum of the eighth abdominal segment; labial palpi never visible. SPHINGOIDEA.

ff. Suture adjacent to the proximal ends of the antennae and separating the front and clypeus obsolete for the greater part of its length; antennae always broadly pectinate and the width at least one fifth of the length and often wider; spiracular furrows seldom present.

SATURNIOIDEA.

PUPAE WITH FUNCTIONAL MANDIBLES

Among the Trichoptera, from which the Lepidoptera are supposed to have descended and to which they are known to be very closely related, there are many pupae which have functional mandibles. They function, though, merely to assist the pupa to escape from the cocoon. Among the generalized Lepidoptera the pupae of one super-

family, the Micropterygoidea, have large mandibles which serve the same purpose as in the Trichoptera.

Superfamily MICROPTERYGOIDEA

The most generalized lepidopterous pupae known belong to the superfamily Micropterygoidea, which includes two families, the Micropterygidae and the Eriocraniidae, characterized by the presence of functional mandibles. Except for a description of the fragments of the head by Chapman, no pupa of the Micropterygidae has been described, but this family is undoubtedly the most generalized, because the adults possess functional mandibles.

The first complete life history of any American species of Eriocraniidae was worked out by Busck and Boeving and published in the Proceedings of the Entomological Society of Washington in 1914 (Vol. XVI, pp. 151-163). These authors gave a short description of the pupa and included some excellent figures. A more detailed description is given here as this species furnishes a working basis for the study of all other lepidopterous pupae. This was made possible by the generosity of Dr. L. O. Howard, Honorary Curator of Insects, U. S. National Museum, who donated some excellent material of *Mnemonica auricyanea* collected this year by Mr. August Busck at Falls Church, Va.

The pupae of this species (Figs. 1, 2, 3) are very small, averaging 3 mm. in length in the males and 4 mm. in the females. The body is covered by a thin transparent cuticle, which shows all the imaginal parts in mature pupae, making it exceedingly difficult to distinguish pupal structures from similar structures in the adult. It is also very difficult to determine the number and position of the setae.

The head shows all the sutures usually present in generalized insects. The vertex is short, the epicranial suture fairly distinct and extending to the lateral margins of the head. The fronto-clypeal suture extends transversely between the caudo-lateral angles of the antennae. The front bears two long straight setae on each side of the meson about half-way between the antennae and the cephalic margin of the head. In the middle of the cephalic aspect, between the antennae, arises a long, fleshy, beak-like projection which contains the long tuft of hairs present in the adult. Just caudad of the front is the clypeus and laterad of these are the genae in the usual position for the Lepidoptera. The suture between the clypeus and labrum is broad and somewhat chitinized, and closely appressed to its ental surface is the tentorium, to which the mandibles are attached. The

labrum is a large fleshy projection bearing on its ectal surface six pairs of very long setae which extend beyond the lateral margin of the body, and on the ental surface two groups of much shorter setae, which project slightly beyond its caudal margin. All of the appendages of the head are free. The labial palpi are rather short, with three segments, and are somewhat enlarged and blunt at the distal end. The mandibles are exceedingly large and are attached to the ental surface of the clypeus, extending beyond the lateral margin of the body. They are heavily chitinized and serrate along the cephalo-lateral margin. The distal end is broadened and thickened, somewhat circular in outline, concave and strongly toothed. The maxillae are short and the halves are widely separated. Each half is strongly bent near the distal end, which is directed cephalad and mesad. The maxillary palpi are long, apparently with six segments, and pass from the mouth dorsad and then out towards the lateral margin of the head, making a series of curves which finally bring them between the eyes and the antennae. The distal end is folded close to the body and lies just caudad of the eye. The antennae show a long pedicel with many shorter segments and extend for more than half the length of the wings.

The thoracic segments are all more or less movable. The thorax is short, strongly elevated, and moves freely, the greater part of its exposed portion being conjunctiva. The mesothorax and metathorax are nearly equal in length, but seem to possess little power of independent motion. On the dorso-meson of these two thoracic segments and the first abdominal segment is found a strap-like cuticular thickening which is apparently for strengthening the thorax. The tegulae are indicated by the dotted lines in Figure 2 because they do not seem to be distinct pupal structures. The thoracic appendages are also free. All of the coxae are visible and usually the femora of the prothoracic and mesothoracic legs. The metathoracic legs are usually hidden beneath the wings except at the distal end, which normally curves around the caudal end of the body. The wings never extend to the caudal margin of the body.

The first seven abdominal segments are movable in both sexes. The remaining segments are not distinctly sutured and possess no power of independent movement. The genital openings are rather difficult to locate. That of the male is found as a slit-like opening on the ventro-meson of the ninth segment (Fig. 4). There are two openings in the female (Fig. 7, go), apparently located on the ventro-meson of the eighth and ninth abdominal segments.

The tenth segment is longer in the female than in the male, presumably on account of the ovipositor. The females always have the eighth, ninth, and tenth segments curved ventrad and closely appressed to the ventral surface of the body. This is shown where the caudal segments are slightly separated from the body, in Figure 2. Figures 6 and 7 give dorsal and ventral views of these caudal segments, and Figures 4 and 5 show the same segments of the male. The anal opening in both sexes is found near the caudal end of the body on the tenth segment. The spiracles are small, circular, and not produced. The mesothoracic spiracle is situated in the conjunctiva connecting the prothorax and mesothorax. Functional abdominal spiracles are visible on segments 2–7. The dorsum of the abdomen is practically covered by very minute spines arranged in groups.

The following species was examined:
Mnemonica auricyanea Walsingham.

PUPAE WITHOUT FUNCTIONAL MANDIBLES

This group includes all the superfamilies of Lepidoptera known, except the Micropterygoidea. In many of the other families the pupae possess mandibles, but they are functionless, and only indicated as small parallel tubercles or lobes.

Generalized pupae without maxillary palpi

The Hepialoidea, together with the Cossoidea and Eucleoidea, differ from all other generalized pupae possessing free abdominal segments cephalad of the fourth, because of the absence of the maxillary palpi. Some of the families included here possess lateral prolongations of the maxillae which resemble maxillary palpi (Figs. 15 and 19) and have been considered as such by some authors. These prolongations never separate from the maxillae at dehiscence, and dissection has failed to find any maxillary palpi present in the mature pupae. None of these superfamilies possess all of the sutures found in the head of the generalized type, and none of them show the long, segmented antennae present in the Eriocraniidae.

Superfamily HEPIALOIDEA

This includes a single family, Hepialidae, of which the known larvae are borers. The species in this country are of rare occurrence. Their larvae are borers in the stems of shrubs or trees. In Europe some of the species are abundant and injurious. The specimens of

Sthenopis thule were obtained through the courtesy of Mr. J. M. Swaine, of the Canadian Department of Agriculture, who obtained them from the stems of willow at MacDonald College, Quebec.

Family Hepialidae

The pupae of this family are very generalized as to the number of sutures present in the head, the number and arrangement of appendages, the comparative length of the mesothorax and metathorax, and the nearly equal length of the first seven abdominal segments. These characters are easily seen in Figures 8–10 and need no further description. The pupae are, however, exceedingly specialized as to the chitinization of the body, the spines, toothed ridges and cutting plates on the abdominal segments, and, more than all, in the soldering down of all the appendages to each other and to the body, exactly as in the most specialized of pupae. The head, thoracic segments, and the first two abdominal segments are firmly soldered together, but abdominal segments 2–7 are free in the male and 2–6 in the female.

The only consolidation of the head parts is that of the clypeus and labrum, between which the suture has been lost. The antennae, as well as all the other appendages, are very short in comparison with the length of the body. These pupae are of considerable size, that of *Sthenopis thule* being about 30 mm. in length. The larvae as far as known are borers, and their pupae have special adaptations for cutting their way to the surface. The most peculiar of these adaptations is the ventral plate on the seventh abdominal segment (best seen in Figure 9), which has not been found in any other pupae examined. The sharp ventral projections on the front also serve as cutting surfaces, but similar projections are found in many pupae, particularly among other species whose larvae are borers and in very many of the leaf-mining species. The opening of the mesothoracic spiracle has reached the normal position for most lepidopterous pupae, being between the prothorax and the mesothorax at each caudo-lateral angle of the former. The genital opening is found in the male on the meson of the ninth segment between two slightly elevated tubercles. In the female there is a single opening apparently on the eighth segment.

The following species was examined:
Sthenopis thule Strecker.

Superfamily COSSOIDEA

The pupae of this superfamily are less generalized as to head parts than the Hepialoidea, but nevertheless resemble them very closely in size, shape and arrangement of the appendages, in the num-

ber of free segments, and in the fact that all the appendages are firmly soldered to each other and to the body. The antennae, however, are of a different type, being pectinate in the Cossoidea. The metathorax varies considerably from the generalized type, being very much shorter, so that the mesothorax is about four times its length, measured on the median line. Many of the species in this superfamily have larvae which are borers, and many of the pupae are fitted to work their way to the surface of a burrow. However, the ventral plate of the seventh abdominal segment, which is so distinct in the Hepialoidea, is not present. All of the pupae have some of the body segments armed with spines and strongly toothed chitinized ridges, and a strong ridge or projection is generally present on the head. The families may be separated as follows:

a. Abdominal segments 2–6 movable in the female and 2–7 in the male; dorsum of abdominal segments armed with a row of sharp spines on the cephalic margin, and a row of setae, which are directed cephalad, on the transverse conjunctiva at the caudal margin; females without wings and antennae and larva-like in appearance. PSYCHIDAE.

aa. Abdominal segments 3–6 movable in the female and 3–7 in the male; dorsum of abdominal segments armed with a toothed ridge along each margin; sexes similar..... COSSIDAE.

Family PSYCHIDAE

In this family there are no sutures apparent on the head except between the clypeus and labrum and the mandibles. The antennae are short and pectinate. The prothorax is longer and the metathorax much shorter than in the Hepialoidea, to which, however, these pupae show many resemblances. The dorsum of the abdomen has toothed chitinized ridges along the cephalic margin of some of the segments and rows of setae along the caudal margin on the transverse conjunctiva. The caudal end of the body bears two large, strong hooks directed ventrad. This description applies mostly to the males (Figs. 11–13), as the females are quite different as seen in Figure 14.

The females never leave the cocoon during their entire life and have no provision for locomotion, even in the adult. It is an astonishing fact that no pupal wings are developed, because in all other families where the adult females are apterous the pupal wings are always developed, sometimes as much as in the males. Neither are there any pupal antennae present, no eye-pieces, nor traces of maxillae. The labrum and mandibles show very distinctly, both being consid-

erably elevated. The legs are scarcely developed, being represented by transverse chitinized elevations on the venter of the thoracic segments. The abdominal segments are much as in the male. They show on the venter the proleg scars, on the dorsum the rows of toothed chitinized ridges and setae, but the body setae are much smaller and difficult to distinguish and are not represented in the figure. A single genital opening is found in the female, on the eighth abdominal segment. No hooks are present at the caudal end of the body. The abdominal spiracles are present on the first eight abdominal segments, but there is no visible opening for the mesothoracic spiracle in either sex. The only genera available for study were Thyridopteryx and Oiketicus. These resemble each other very closely and the difference between the pupae can hardly be considered as generic. The pupae of Oiketicus are larger and stouter, the males examined averaging 18 mm. in length, while those of Thyridopteryx were slenderer and only 15 mm. in length. The two genera may be separated thus:

a. Abdominal segments 2–6 with a caudal row of setae, the row on the the sixth interrupted and shorter than the other rows; caudal spines stout and simple; spiracles scarcely produced beyond the surface of the body except at their cephalic margins.
Thyridopteryx Stephens.

aa. Abdominal segments 2–5 with a caudal row of setae, no row on the sixth ever present; caudal spines slender and with a distinct tooth; spiracles distinctly produced beyond the surface of the body.
Oiketicus Guilding.

The following species were examined:
Thyridopteryx ephemeraeformis Haworth
Oiketicus abbotii Grote

Family Cossidae

The Cossidae are borers in the larval stage and seem to be very closely related to the Hepialidae, although they resemble them less than do the Psychidae. This family has segments 3–7 of the abdomen free in the male and 3–6 in the female. There is another sexual difference to be noted, viz., the presence of an extra row of spines on the abdomen of the male. In this sex the seventh segment has two rows of spines and the succeeding segments one row; in the female the sixth is the last segment with two rows, the remaining caudal segments having but one row. The epicranial suture is not distinct in any species, but at dehiscence *Prionoxystus robiniae* shows a small piece of the vertex on each side of the meson, and this with the conjunctiva bears the eye-pieces. The lateral part of the fronto-clypeal suture is distinct and the clypeo-labral suture is always visible.

This family is usually divided into subfamilies of which two, the Cossinae and Zeuzerinae, are discussed here. Figure 15 shows the ventral surface of the head and its appendages in a member of the Cossinae, the arrangement of the other parts being the same as in the Zeuzerinae (Fig. 16).

The maxillae have prominent lateral projections in Cossinae which resemble maxillary palpi. These always adhere to it at dehiscence and are not found in Zeuzerinae. Only one genus of each subfamily was studied. The pupae are very large, those of *Prionoxystus robiniae* and *Zeuzera pyrina* being respectively 45–50 mm. and 30–35 mm. in length. The two genera studied may be separated as follows:

a. Head without a prominent cephalic projection; maxillae with an apparently segmented lateral projection on each side resembling a maxillary palpus, but adhering to the maxillae at dehiscence; antennae more than half the length of the wings and gradually tapering; abdominal segments with the cephalic ridges much larger than the caudal ones and armed with long even teeth.
Prionoxystus Grote.

aa. Head with a prominent cephalic projection, maxillae never with an apparently segmented lateral projection on each side; antennae less than half the length of the wings and narrowed abruptly near the middle; abdominal segments with the cephalic and caudal ridges similar, the teeth short and uneven.....*Zeuzera* Latreille.

The following species were examined:
Prionoxystus robiniae Peck
Zeuzera pyrina Linnaeus

Superfamily EUCLEOIDEA

The pupae of this superfamily are quite specialized as to the head parts, the epicranial suture being the only one visible in all the families. They have followed a very different line of development from the Cossoidea and Hepialoidea, because all of the generalized families retain freedom of motion between all the segments except those fixed at the caudal end of the abdomen, and between all of the appendages. The cuticle is very thin and transparent in almost all genera and the dorsum of the abdominal segments in all of them has a covering of small spines over the greater part of the segment. All of the families show the spiracles distinctly on the first abdominal segment. The only other family in which this was observed, the Nepticulidae, has a well-developed maxillary palpus. The mesothoracic spiracle of each side is in a rather unusual position in this

superfamily. The opening is on the dorsum in the normal position, and is very large, with a strongly arched cephalic margin; but the spiracle is on the ventral surface directly under the sculptured eye-piece in Megalopygidae and Eucleidae, and a little farther laterad in Pyromorphidae so that it comes partly under the antennae. The spiracle, with the adjoining parts slightly pushed aside to show their relation, is seen in Figure 21. The family Pyromorphidae being more specialized than the other two families differs from them considerably, but its relationship to them is evident. The three families included here may be separated as follows:

a. Dorsum of abdominal segments with spines on the cephalic part and a covering of coarse setae on each caudo-lateral part which does not usually extend to the meson; maxillae simple quadrangular pieces, without any lateral prolongations; a large conical tubercle caudad of each abdominal spiracle on segments 2–6; mesothorax never extending caudad to the first abdominal segment.....MEGALOPYGIDAE.

aa. Dorsum of abdominal segments with short spines, but never with a covering of coarse setae on any part; tubercles never present caudad of any of the abdominal spiracles.

b. Labial palpi present; mesothorax with a long mesal lobe reaching on to the first abdominal segment; maxillae always less than half the length of the wings.....PYROMORPHIDAE.

bb. Labial palpi absent; mesothorax never with a long mesal lobe reaching on to the first abdominal segment; maxillae more than half the length of the wings.....PYROMORPHIDAE.

Family MEGALOPYGIDAE

The Megalopygidae have the head and thoracic segments free, also abdominal segments 1–7 in the male and 1–6 in the female. The appendages are entirely free from each other and from the body wall. The body is soft and covered with a thin, delicate, transparent cuticle which is slightly chitinized. There are always setae on the dorsum of the abdominal segments as well as spines. The setae are found on each side of the meson on the caudal half of all the segments. The epicranial suture is distinct but all the other head sutures are obliterated. The front has a distinct projection and the mandibles show as distinctly elevated tubercles. The size and arrangement of the parts may be seen in Figures 17 and 18. This family together with the Eucleidae possesses a very peculiar eye-piece. Chapman ('94, p. 349) called attention to this structure and spoke of it as the "eye-flange". This eye-piece, in reality the sculptured portion, is free along its lateral and caudal margins and extends well out on to the antennae.

It is, however, much more wrinkled and sculptured than any other portion of the body. These eye-pieces move up and down in living pupae during respiration and allow one to see the mesothoracic spiracle underneath. The mesothorax possesses some well-defined alar ridges and its caudal margin extends in a broad curve nearly to the caudal margin of the metathorax. The large conical tubercles are found caudad of the spiracles on abdominal segments 2–6. The body of *Lagoa crispata* Packard, the only species studied, is strongly arched on the dorsum of the abdomen and is short and thick-set. Its length is about 18 mm. and the greatest breadth 10 mm.

The following species was examined:

Lagoa crispata Packard.

Family Eucleidae

The Eucleidae retain the same movable segments as the family Megalopygidae, which they strongly resemble. The pupae of Eucleidae, however, are usually only half the size of the latter, averaging about 9 mm. in length. They also retain the same head sutures, but, as in Prolimacodes, they often show a distinct furrow marking the position of the lateral part of the fronto-clypeal suture. The eye-pieces are identical with those described for Megalopygidae. The size and arrangement of parts may be seen in Figures 19, 20, and 23. In two of the genera studied, Sibine and Euclea, the maxillae, in addition to the usual cephalo-lateral extension found throughout the family (Fig. 23), have peculiar modifications in the form of long lateral prolongations extending to the antennae. Usually only the distal end of this prolongation is seen between the eye-piece and the antennae, as in Figure 19, the dotted line showing the connecting part. These two genera also have a distinct groove in each half of the maxillae, into the caudal part of which the femur of the prothoracic leg is fitted. The cephalic margin of the pronotum has a distinct median notch, which makes it appear bilobed, and each lobe is prolonged cephalad over the caudal margin of the head (Fig. 22). The mesonotum is prolonged into a rounded or pointed lobe which reaches on to the first abdominal segment. Only three genera were available for study. These may be separated by the following table:

a. Maxillae never with a lateral projection reaching to the antennae; mesothorax with a strongly carinate median line; caudal lobe of the mesonotum broadly rounded..... *Prolimacodes* Schaus.

aa. Maxillae with lateral projections reaching to the antennae; mesothorax never with a strongly carinate median line.

b. Mesonotum with the caudal lobe pointed..... *Euclea* Hübner.

bb. Mesonotum with the caudal lobe broadly rounded, almost truncate ..... *Sibine* Herrich-Schaeffer.

The following species were examined:
Prolimacodes scapha Harris
Euclea delphinii Boisduval, *chloris* Herrich-Schaeffer
Sibine stimulea Clemens

Family Pyromorphidae

This family is much more specialized than either the Megalopygidae or the Eucleidae and resembles them but little. The body is flattened and has lost the power of motion except in the abdomen. Abdominal segments 2–7 are free in the male and 2–6 in the female. The appendages are also very slightly soldered together. The presence of spines on the abdominal segment, together with the absence of maxillary palpi, is considered sufficient evidence that it belongs to the superfamily Eucleoidea. Figures 24 and 25 show the essential points of its structure. The only genus available for study was Harrisina.

The following species was examined:
Harrisina americana Guérin-Méneville.

Generalized pupae with maxillary palpi

The remaining pupae which retain either free segments cephalad of the fourth abdominal segment or free appendages, have followed two distinct lines of development. In the first group the generalized condition of the body found in the Eriocraniidae has been retained as to comparative length of segments and the covering of the dorsum of the abdomen with fine spines. The metathorax is nearly always more than half the length of the mesothorax, while the prothorax tends to become shorter at the meson and broader at the lateral margins, so that each half appears triangular. In the second group, the covering of spines on the dorsum of the abdomen has been gradually changed and there is one very well-developed row of spines at the cephalic margin of each segment, with or without a similar caudal row. In this group the prothorax is longer and somewhat quadrangular in shape and the metathorax is relatively shorter. This group includes the superfamilies Tineoidea and Tortricoidea, and being much smaller than the other will be considered first.

Superfamily TINEOIDEA

The families included here possess one row of spines along the cephalic margin of the dorsum of the abdominal segments, and well-developed maxillary palpi. In one family, Prodoxidae, the primitive

covering of fine spines has been retained, but it may be easily differentiated from all other pupae bearing spines of two sizes in a similar position on account of the large maxillary palpi.

The family Heliodinidae is included here for the sake of convenience as it possesses only the cephalic row of spines on the dorsum of the abdominal segments. It is, however, much more nearly related to the Tortricoidea. The families Prodoxidae and Acrolophidae are more nearly related to the Tineidae. Of these the Prodoxidae are undoubtedly the most generalized, retaining more head sutures and a greater number of free segments, in addition to the spines mentioned above. The Acrolophidae are more generalized than the Tineidae in the matter of free segments, but have the appendages firmly soldered to each other and to the body wall. This is probably due to the fact that the larvae are sod-borers and that the pupa works its way to the surface. The families may be separated as follows:

a. Mesonotum not produced into a long caudal lobe; mesothorax seldom more than twice the mesal length of the metathorax.
  b. Abdominal segments 2–7 movable; dorsum of abdominal segments with a covering of spines on the caudal part; maxillae more than twice as long as the labial palpi.....PRODOXIDAE.
  bb. Abdominal segments 3–7 movable; dorsum of abdominal segments never with a covering of spines on the caudal part; maxillae shorter than the labial palpi.
    c. Antennae never extending to the caudal margin of the wings; wings broadly rounded; appendages firmly soldered to each other and to the body; a lateral projection never present on each side of the tenth abdominal segment.....ACROLOPHIDAE.
    cc. Antennae extending beyond the caudal margin of the wings; wings pointed; appendages only slightly soldered together and separating at the slightest touch; tenth abdominal segment with a prominent lateral projection on each side ending in a spine.....TINEIDAE.
aa. Mesonotum produced into a long caudal lobe; metathorax never more than one fourth the mesal length of the mesothorax.
HELIODINIDAE.

Family PRODOXIDAE

In this family abdominal segments 2–7 are free in both sexes. The head shows the epicranial suture plainly, and dehiscence always takes place on the front of the head along what is apparently the frontoclypeal suture, at least for a part of the distance, as shown in Figure 26. The front bears a prominent chitinized projection armed with two stout teeth. The lateral margin of the eye-piece extends on to the antenna for a very short distance. The appendages are very

slightly soldered to each other, but scarcely to the body wall, and separate very easily. The lateral view, Figure 27, shows the relative length of the segments. The abdominal segments, although they have developed a prominent cephalic row of spines on the dorsum, still retain the covering of very fine spines on the remainder of the segment. The eighth abdominal segment bears a pair of very stout hooks at the apices of rounded tubercles (Fig. 27a). The pupae examined measured about 10 mm. in length.

The following species was examined:
Prodoxus quinquepunctella Chambers.

Family Acrolophidae

In this family segments 3–7 of the abdomen are movable in both sexes, but the appendages are quite firmly soldered to each other and to the body wall so that they do not readily separate even at dehiscence. There is probably also dorsal movement of the second segment, as the conjunctiva is well developed and both the first and second segments separate at dehiscence. The larvae of members of this family are sod-borers and it seems quite natural that pupae with this mode of life should have their appendages soldered down at a much earlier stage than those of the leaf-miners, for instance, or of the pupae that live in cocoons. There are none of the small spines of the generalized type present on the dorsum of the abdomen in this family, but a well-developed row of spines at the cephalic margin of the segments. There are also short lateral and dorsal projections of the tenth segment, with very sharp chitinized edges, which are evidently to aid the pupa in working its way to the surface. The head bears a strongly chitinized transverse ridge near the cephalic margin of the ventral surface. Figures 28 and 29 show the arrangement of parts in a pupa of this family in which there is a remarkable development of the labial palpi. The pupae are from 15–20 mm. in length. The genera may be separated as follows:

a. Labial palpi never with distinct cutting plates near their proximal margin, the palpi not extending much over half the distance to the distal ends of the prothoracic legs; two pairs of coxae visible; spines of the abdominal segments long and narrow.
Hypocolpus Walsingham.

aa. Labial palpi with distinct cutting plates near their proximal margin, the palpi extending as far as the distal ends of the prothoracic legs; a single pair of coxae visible; spines of the abdominal segments triangular ..... *Pseudanaphora* Walsingham.

The following species were examined:
Hypocolpus mortipennellus Grote
Pseudanaphora arcanella Clemens

Family Tineidae

In this family the free abdominal segments are 3–7 in the male; no females were available for examination. Segments 1–3 separate dorsally at dehiscence. The appendages are very slightly soldered together and all separate readily except the metathoracic legs and antennae, which extend beyond the caudal margin of the wings and are quite firmly fastened together, the legs being underneath the antennae.

The appendages are also slightly soldered to the body as far as the third abdominal segment. The arrangement of parts is shown in Figures 30 and 31. The fronto-clypeal suture is indicated by a clear line in the otherwise fairly well-chitinized cuticle. Segments 3–8 of the abdomen bear a cephalic row of spines on the dorsum directed caudad, while the ninth segment bears an interrupted group of spines directed cephalad. There are none of the fine spines of the generalized type of pupa present in this family. The tenth abdominal segment shows a prominent lateral projection on each side, ending in a spine. The setae of the body are very conspicuous. The pupae are about 4 mm. in length.

The following species was examined:
Tinea pellionella Linnaeus.

Family Heliodinidae

This family has usually been associated with the Yponomeutidae, but it seems from pupal characters to be more closely related to the tortricids. It is very similiar to these in arrangement of parts; the Heliodinidae, however, have longer maxillae and they plainly show that dorsal motion is possible between the second and third abdominal segments. There are also curved setae at the caudal end of the body in the genus Brenthia (Figs. 32 and 33) strongly resembling those found in the Epiblemidae. Choreutis (Figs. 34 and 35) has a small dorsal plate on the tenth segment with a strong seta at each end which appears to represent an early state in the development of a cremaster. The possession of a single row of dorsal spines on the abdominal segments, however, is like the remainder of the Tineoidea, and it is easier to classify them as such. They differ from the remainder of the superfamily in having one more free segment in the male, abdominal segments 3–7 being free in the male and 3–6 in the female. The thorax

differs markedly, too, the prothorax and metathorax being much shorter. The mesonotum has its caudal margin produced into a long lobe, while in the other families the caudal margin of the mesonotum is very slightly curved. The appendages are very slightly soldered to each other and to the body, and the wings reach on to the fourth abdominal segment. The spiracles are small, circular, and very slightly produced. The pupae are from 6–8 mm. in length. The genera may be separated as follows:

a. Body setae longer than the abdominal segments, heavily chitinized and forked at the end; maxillae, measured on the meson, about half the length of the wings; abdominal segments without deep punctures along the cephalic margin, but with a row of sharp triangular spines.
Brenthia Clemens.

aa. Body with very short inconspicuous setae; maxillae extending to the caudal margin of the wings; abdominal segments 2–6 with a row of deep punctures along the cephalic margin, and with a row of sharp triangular spines just cephalad of the punctures.
Choreutis Hübner.

The following species were examined:
Brenthia pavonacella Clemens
Choreutis inflatella Clemens, *gnaphiella* Kearfott

Superfamily AEGERIOIDEA

The Aegerioidea, together with the Tortricoidea retain freedom of movement in abdominal segments 3–7 in the male and 3–6 in the female. The appendages are soldered to the body so that there is no ventral movement possible between the first two abdominal segments; but there is undoubtedly dorsal movement, and at dehiscence these segments separate very distinctly from each other and the thorax, indicating that they have only recently lost their power of motion. In this superfamily is included the one family Aegeriidae. They form a very compact group in which it is hard to find satisfactory characters differentiating the genera. Moreover, pupae in good condition are difficult to obtain; but it is hoped that the characters used here in separating the genera and in defining the superfamily will hold good for those groups to which they are applied. The sexes vary considerably and it has not been possible in all cases to obtain both male and female. This superfamily has most often been associated with the Tineoidea, but pupal characters indicate a much closer relationship to the Tortricoidea. It is apparently somewhat nearer to the primitive families Eriocraniidae and Nepticulidae than the Tortricoidea, owing to the

fact that a very large maxillary palpus is present in all genera, and that spines which reach well around to the ventral surface are found on abdominal segments 2–10, especially on the tenth segment. There are no setae yet developed on the anal rise, and there is not as much consolidation of the fixed caudal abdominal segments. The seventh segment in the female seems but recently to have lost power of motion. The abdominal segments are more nearly equal in length than in the Tortricoidea.

Family Aegeriidae

The pupae of this family vary considerably in size, from the genus Aegeria, with species varying from 8–16 mm. in length, to the genera Memythrus and Bembecia, containing the largest species examined, varying from 20–25 mm. They are all provided with various forms of cutting plates for working their way to the surface, most of these being on the head, which is heavily chitinized at the cephalic end and usually has many ridges and projections, making it difficult to determine the sutures. The clypeus often bears a sharp transverse ridge, sometimes toothed, which undoubtedly serves the same purpose. The body is elongate, cylindrical, with the abdominal segments approximately equal in length, showing a generalized condition. The arrangement of parts in a pupa of this family is shown in Figures 36 and 37. It will be noted that the maxillary palpi are very large, and they remain uniformly so throughout the family. The appendages extend beyond the wings in most of the genera, but the caudal parts of these are not soldered to the body wall. The fronto-clypeal suture is always distinct along the lateral margins of the front from the proximal ends of the antennae almost to the invaginations for the anterior arms of the tentorium, but only shows transversely as a paler band of color in the strongly chitinized cuticle as indicated by the dotted line in Figure 36. Dehiscence invariably follows the course of this suture, and the front with the antennae are separated from the rest of the head parts. The epicranial suture is often obscured by the numerous elevations of the vertex and front, but it is always present. The antennae are always enlarged at the proximal end and again at the distal end, where they are somewhat club-shaped, thus differing again from the Tortricoidea. The mandibles are distinctly elevated in most genera. The wings are narrow and pointed, differing markedly from those of the Tortricoidea. They are not soldered to the body wall at their distal end. The thorax always has a carinate median ridge, which may be distinct on all the segments, and is always distinct on the prothorax and the cephalic half of the mesothorax. The alar furrows are very deep, and one edge, usually the mesal one, is sharp and heavily chitinized. There are always two rows of spines on the dorsum of some of the abdom-

inal segments, which extend around to the ventral surface. These rows of spines are always present on segments 3–6, the number varying on segments 2 and 7, while there is always one row on segments 8–10. The number of rows of spines on segment 7 differs in the sexes, there being two rows in the male and only one in the female. The spines on the tenth segment are very broad, and this row extends nearly to the ventro-meson. Each of the spines has a seta inserted near its tip, which is not heavily chitinized and therefore easily broken. There are never any setae present on the anal rise. The genera of Aegeriidae may be separated as follows:

a. Maxillae always more than half the length of the wings, generally nearly or quite equaling their length; coxae of mesothoracic legs never adjacent on the meson below the maxillae.
  b. Clypeus with a prominent elevation near its caudal margin, bearing a heavily chitinized transverse ridge or series of projections which are probably to assist the pupa in cutting its way out of the burrow.
    c. Clypeus with the chitinized transverse ridge produced into a distinct point on each side of the meson.
      d. Mesothorax with the median carinate ridge extending nearly its whole length, very distinct on the metathorax; second abdominal segment with the two rows of spines distinct in both sexes; maxillae never reaching the caudal margin of the wings and ending opposite to the antennae; pupae averaging 20–25 mm. in length ..... *Sanninoidea* Beutenmüller.
      dd. Mesothorax with the median carinate ridge usually extending only along the cephalic half, never distinct on the metathorax; second abdominal segment never with two distinct rows of spines in either sex; maxillae reaching the caudal margin of the wings and ending opposite the mesothoracic legs; pupa usually 8–15 mm. in length.
      Synanthedon Hübner.
    cc. Clypeus with a transverse row of separate projections.
    Parharmonia Beutenmüller.
  bb. Clypeus not prominently elevated at its caudal margin and never bearing ridges or projections which could be used in cutting.
    c. Tenth abdominal segment with eight spines in a row; caudal end of body just cephalad of the anal opening without setae.
    Podosesia Möschler.
    cc. Tenth abdominal segment with ten large spines in a row and two smaller ones, one on each side of the meson; caudal end of body just cephalad of the anal opening with a row of four setae which are inserted under small projections.
    Memythrus Newman.
aa. Maxillae about two fifths the length of the wings; coxae of mesothoracic legs and their tarsi adjacent on the meson caudad of the maxillae..... *Bembecia* Hübner.

The following species were examined:
Sanninoidea exitiosa Say
Synanthedon tipuliformis Clerck, *acerni* Clemens, *pictipes* Grote and Robinson, *pyri* Harris, *scitula* Harris
Parharmonia pini Kellicott
Podosesia syringae Harris
Memythrus asilipennis Boisduval, *dollii* Neumoegen
Bembecia marginata Harris

Superfamily TORTRICOIDEA

This superfamily, like the Aegerioidea, is distinguished by the presence of two rows of spines on the dorsum of most of the abdominal segments. The Tortricoidea form a more compact group than the Aegerioidea in regard to the arrangement of appendages, which varies so little throughout the families that any member of the superfamily may be easily recognized by this arrangement, together with the presence of spines on the abdominal segments. This characteristic arrangement is shown in Figures 38, 40, 41, and 44. There are often projections from the head, much as in the Aegerioidea, but there are never as many head sutures present. The thorax shows the alar furrows in many instances but they are never as well developed as in the preceding superfamily, and never have sharp chitinized edges. The abdomen also shows a greater degree of specialization and its fixed caudal segments are much more strongly consolidated, the sutures being very difficult to determine in many cases. The seventh segment has also become firmly fixed in the female.

It was found impossible to group the pupae of this superfamily according to any of the schemes of classification now in use. The four groups into which the Tortricoidea discussed in the following pages have been divided are designated as Epiblemidae, Olethreutidae, Tortricidae, and Sparganothidae. These names, however, are without any significance whatever as far as previous classifications are concerned, and are merely used as a matter of convenience. Lack of material has prevented further study in this group at present, so it has been impossible to determine the correct family names. No attempt has been made to bring the nomenclature up to date. The generic names used by Meyrick and Walsingham have been followed as nearly as possible.

The four groups or families of Tortricoidea must have had a common ancestor, but owing to the development of the maxillary palpus within the groups it would be impossible to consider one as derived from another. The line of development appears to have

been towards (1) a reduction of the spines on the dorsum of the abdominal segments, these disappearing first from the tenth segment and then from the segments cephalad of it; (2) the loss of setae on the anal rise; and (3) the development of a long cremaster. The families of Tortricoidea may be separated by the following table:

a. Body without a distinct cremaster; setae always present on the anal rise ..... EPIBLEMIDAE.

aa. Body with a well-developed cremaster.

b. Ninth abdominal segment always with a distinct row of spines, especially in the males; tenth abdominal segment sometimes possessing spines; cremaster broader than long; setae always present on the anal rise.

c. Cremaster never curved ventrad, the caudo-lateral angles not produced into prominent hooks; the caudal margin usually showing three short lobe-like projections; second abdominal segment with the cephalic row of spines present and the caudal row well developed; setae of the anal rise always laterad of the anal opening ..... OLETHREUTIDAE.

cc. Cremaster curved ventrad, the caudo-lateral angles produced into prominent hooks; second abdominal segment lacking the cephalic row of spines and the caudal row poorly developed; setae of the anal rise always on the caudal part of the elevation ..... TORTRICIDAE.

bb. Ninth abdominal segment lacking a distinct row of spines, although a few spines are sometimes present in the males; setae never present on the anal rise; cremaster nearly always longer than broad; tenth abdominal segment never possessing spines. SPARGANOTHIDAE.

Family EPIBLEMIDAE

The pupae belonging to this family (Figs. 38, 39) have no cremaster and there are always setae present on the anal rise. They are usually less than 10 mm. in length and slender, tapering gradually from the thoracic region to the somewhat blunt end of the body. The genus Carpocapsa is sometimes an exception as the body is often very stout, and the genus Eucosma has a cylindrical body strongly resembling the pupae of the Aegeriidae. The maxillary palpi usually extend to the proximo-lateral angles of the maxillae; only Epinotia and Enarmonia of the genera studied had shorter palpi. The maxillae are about two fifths the length of the wings, and the labial palpi are usually half the length of the maxillae. The rows of spines on the dorsum vary somewhat in the different genera. All have two rows present on abdominal segments 2–7 although the cephalic row of segment two is weak in Eucosma, Hemimene, and some species of Ancylis. Occa-

sionally the caudal row of segment seven is weak in the females of some species. As a general rule the eighth segment has but one row of spines, the cephalic one, but two rows have been found in the species of Epinotia and Eucosma, usually in the males. There is, in most genera, considerable difference between the sexes. The antennae do not vary as greatly in this family as in some others, but there is a great variation in the rows of spines, these being usually smaller and less numerous on the caudal row of segment seven in the male and on segment eight in the female. The genus Mellisopus does not show characters of sufficient importance to allow of its retention as a separate genus, and it is therefore included with Carpocapsa. The only points of difference between that genus and *Carpocapsa pomonella*, its nearest ally, are that the spiracles are oval, somewhat rectangular and slightly produced, while in *Mellisopus latiferreanus* they are large and circular but not strongly produced. There is however considerable variation. Mellisopus shows a slight carinate ridge on the metathorax, but this, again, is extremely variable.

The phylogeny of the group is extremely doubtful. If the spines on the dorsum of the abdominal segments in Eucosma were homologous with those found in the generalized pupae of Nepticulidae and others, it would certainly be the most generalized form and the others would probably follow the sequence of the table to genera. The spines, however, are much broader than any observed in the generalized types. Eucosma also shows a remarkable resemblance to the Aegeriidae, so it is probable that it is the most generalized of the Tortricoidea examined. The genera of Epiblemidae may be separated as follows:

a. With two long distinct setae present on each side of the anal rise.
  b. Caudal end of body with one row of long, heavily chitinized, flattened setae inserted along the line of the row of spines on the tenth abdominal segment.
    c. Dorsal surface of abdominal segments between the cephalic and caudal rows of spines covered, at least in part, with short triangular spines; cephalic row of spines composed of alternating large and small spines.....*Eucosma* Hübner.
    cc. Dorsal surface of abdominal segments between the caudal and cephalic rows of spines always smooth; cephalic row of spines of approximately the same size.
      d. Portion of first coxae exposed on the meson below the maxillae more than half the length of the second coxae; body often stout, with the length scarcely three times the greatest width, but extremely variable; length averaging 10 mm.
Carpocapsa Treitschke.

dd. Portion of first coxae exposed on the meson below the maxillae never more than half the length of the second coxae; body always slender, with the length about four times the greatest width; average length 8 mm.....*Tmetocera* Lederer.

bb. Caudal end of body with two rows of setae showing, one row of four setae inserted along the line of the row of spines on the tenth abdominal segment and another row at the caudal margin of the body.

c. Caudal row consisting of four setae; maxillary palpi always touching the proximo-lateral angles of the maxillae.

d. Caudal row of setae of two kinds, the mesal ones much slenderer than the lateral ones; maxillae less than one third the length of the wings; labial palpi about two thirds the length of the maxillae; maxillary palpus touched by the prothoracic leg .....*Hemimene* Hübner.

dd. Caudal row of setae similar; maxillae never less than one third the length of the wings; labial palpi about half the length of the maxillae; maxillary palpus touched by both prothoracic and mesothoracic legs.....*Ancylis* Hübner.

cc. Caudal row consisting of two setae; maxillary palpi seldom reaching the proximo-lateral angles of the maxillae.
Epinotia Hübner.

aa. Never with two long, distinct setae on each side of the anal rise.

b. Lateral spines of the tenth row noticeably larger than the others; setae at the caudal end of the body very short and slender, not heavily chitinized; setae of the anal rise very small and difficult to locate, usually two present on each side.....*Thiodia* Hübner.

bb. Lateral spines of the tenth row not noticeably larger than the others; setae at caudal end of body long and heavily chitinized; one seta on a distinct papilla on each side of the anal rise.
Enarmonia Hübner.

The following species were examined:

Eucosma strenuana Walker, *scudderiana* Clemens

Carpocapsa pomonella Linnaeus, *saltitans* Westwood, *latiferreanus* Walsingham

Tmetocera ocellana Schiffermueller

Hemimene incanana Clemens

Ancylis comptana Frolich, *platanana* Clemens, *diminutana* Kearfott

Epinotia saliciana Clemens, *piceafoliana* Kearfott

Thiodia signatana Clemens

Enarmonia fana Kearfott

Family Olethreutidae

The Olethreutidae (Fig. 40) include those species which possess a well-developed cremaster, usually broader than long and somewhat

flattened, bearing eight strongly chitinized, flattened, hooked setae; and usually having similar but smaller setae on the anal rise. Exceptions to this latter character are found in the genus Polychrosis, and in *Exartema ferriferanum,* which does not agree with the remainder of the genus in this respect. The group is further characterized by the presence of a well-developed row of spines on the ninth abdominal segment in all the males examined and in nearly all of the females, the exceptions being in the genus Exartema, where the spines were smaller and fewer in number. In most genera this row of spines has several additional spines on each side, usually near the meson. The only other species of the superfamily which resemble the members of this group are the species of Archips in group (b), but these have no setae on the anal rise, and very seldom have spines present on the ninth abdominal segment. *Exartema ferriferanum* is the only species among those examined which might be confused, as the row of spines on the ninth segment of the female is not well developed, while the males of *Archips cerasivorana* sometimes have a few spines present. This particular species of Exartema, however, has a prominent cephalic projection, ending in a point, directed ventrad, while the species of Archips are blunt at the cephalic end, and the bodies are usually larger and prominently enlarged in the region of the thorax. The antennae show marked sexual differences, being much longer in the males. The rows of spines on the dorsum of the abdominal segments also vary in the sexes, the caudal row of segment eight being poorly developed or lacking in many females, though well developed in the males. The row on the ninth segment is much better developed in the males. The genus Polychrosis shows a peculiar development of the spiracles. Instead of the small, produced tubular spiracles common to the Tortricoidea it appears to have them very much enlarged. This prominent enlargement around the spiracle has a deeply concave surface, and the very small tubular spiracle in the center is about one sixth of its width. A similar condition, but not so well developed, is found in *Exartema sciotoanum.* The maxillary palpi are well developed and reach the proximo-lateral angles of the maxillae in Olethreutes (b) and Polychrosis, but in Episimus, Olethreutes (a), and Exartema they are not well developed. The genera of Olethreutidae may be separated as follows:

a. Tenth abdominal segment with spines, usually three or four rows closely approximated, seldom with a single row.
  b. Long chitinized setae present on the anal rise, usually slightly shorter and narrower than those of the cremaster.
    c. With two setae on each side of the anal rise, very similar to those on the cremaster.....*Episimus* Walsingham.

cc. With one seta on each side of the anal rise, smaller than those of the cremaster.....*Olethreutes* (a) Hübner.
bb. Setae never present on the anal rise.....*Polychrosis* Ragonot.
aa. Tenth abdominal segment without spines.
b. Well-developed setae present on each side of the anal rise.
c. Maxillary palpi well developed, reaching the proximo-lateral angles of the maxillae.....*Olethreutes* (b) Hübner.
cc. Maxillary palpi short, never reaching the proximo-lateral angles of the maxillae.....*Exartema* (a) Clemens.
bb. Without setae on the anal rise.....*Exartema* (b) Clemens.

The following species were examined:
Episimus argutanus Clemens
Olethreutes (a) *niveiguttana* Grote, (b) *malachitana* Zeller
Polychrosis slingerlandana Kearfott, *vitcana* Clemens, *botrana* Schiffermueller
Exartema (a) *sciotoanum* Kearfott, *concinnanum* Clemens, *nigranum* Kearfott, *inornatum* Clemens, *permundanum* Clemens
Exartema (b) *ferriferanum* Walker

Family Tortricidae

This group is distinguished by its peculiar type of cremaster and the presence of setae on the anal rise. The maxillary palpi are not present in Peronea but are found in Argyrotoxa, where they are shorter in the male than in the female. The maxillae are usually about two fifths the length of the wings, the labial palpi nearly half the length of the maxillae. There are no spines present on the tenth abdominal segment, and they are not well developed on the second and third segments. There is always a well-developed cephalic row on the dorsum of the tenth segment, but the caudal one does not extend as far laterad in the male and is usually lacking in the female. In Argyrotoxa the cephalic row of spines on the eighth and ninth segments is on a prominent ridge which can be plainly seen on the lateral margin in dorsal view. There are always two setae present on each side of the anal rise and these are always on the caudal part of the elevation. Figures 41 and 42 show the arrangement of parts in this family and Figure 43 the dehiscence of part of the head, showing the eye-piece. The genera of Tortricidae may be separated by the following table:

a. Maxillary palpi present in both sexes; spines of the cephalic row on abdominal segments 7–9 on distinct ridges which show plainly on the lateral margins of the body, the spines extending laterad beyond the spiracles in some segments; setae on the ventral side of cremaster and between cremastral hooks not heavily chitinized and resembling the ordinary body setae.....*Argyrotoxa* Stephens.

aa. Maxillary palpi not present in either sex; spines of the cephalic row on abdominal segments 7–9 not on distinct ridges, the spines never extending laterad beyond the spiracles; setae on the ventral side of cremaster heavily chitinized, and usually not extending far beyond the caudal margin of the body.....*Peronea* Curtis.

The following species were examined:
Argyrotoxa albicomana Clemens, *bergmanniana* Linnaeus
Peronea sp., *minuta* Robinson, *logiana* Schiffermueller, var. *viburnana* Clemens

Family Sparganothidae

This family (Fig. 44) includes the species in which the cremaster is well developed and much longer than broad, except in Archips (b) and Phaecasiophora. The cremaster in nearly all species bears eight strong hooked setae which are usually not much flattened except in the genera mentioned above. There are never any setae present on the anal rise, and most of the species have no spines present on the ninth abdominal segment and none of them a well-developed row. The caudal row of the eighth segment is often lacking in the female and is poorly developed in the male. The females of *Platynota flavedana* have no cephalic row on the second abdominal segment. The members of this group include the largest of the Tortricoidea examined, most of them considerably over 10 mm. in length; the thoracic region usually appears considerably enlarged, and the abdomen is long and tapering. The vertex is shorter than in the other groups. The maxillary palpi do not reach the proximo-lateral angles of the maxillae in the males, but sometimes do so in the females. In *Platynota flavedana* the palpi appear to extend only along the cephalic margin of the prothoracic leg. The setae of the body are usually very long and prominent in this group. Sexual differences are noticed in the length of the maxillary palpi and antennae and in the development of the rows of spines on the dorsum of the abdominal segments. There are no available characters by which all the species of the genus Archips can be associated in a single group and it undoubtedly represents two genera, because there are two distinct types of cremaster present. It is also difficult to find good structural characters to separate the genera Harmologa and Archips (a). The color markings are very distinct in Harmologa, and the body is also very noticeably enlarged in the region of the first three abdominal segments, so that in ventral view the lateral margins of the wings appear curved, instead of approximately parallel as in Archips (a). The genera Epagoge and Platynota are also closely related and are grouped together by some writers. The genera of Sparganothidae may be separated as follows:

a. Transverse conjunctiva showing prominent dark brown spines sca
tered over a lighter brown surface.
b. Cremaster much longer than broad, not flattened.
c. With four setae inserted at the caudal end of the cremaster.
d. Dorsum of second abdominal segment showing a slightly crem
late, chitinized cephalic margin, the cephalic row of spines c
this segment not well developed in the males and wanting i
females; head never with a cephalic projection; abdome
never with prominent cavities on the dorsum of the secon
and third segments; dorsum of abdomen always with dark
transverse bands and spots of color.....*Harmologa* Meyric
dd. Dorsum of second abdominal segment without a crenula
cephalic margin; cephalic row of spines well developed c
this segment in both sexes; head often with a cephalic pr
jection, or if not, then prominent cavities are present on tl
dorsum of the second and third abdominal segments; bod
of uniform color.....*Archips* (a) Hübne
cc. With two setae inserted at the caudal end of the cremaster.
Cenopis **Zelle**
bb. Cremaster broader than long, flattened.....*Phaecasiophora* Grot
aa. Transverse conjunctiva never showing prominent dark brown spine
surface of uniform color.
b. Cremaster longer than broad, not flattened; labial palpi alwa
considerably more than half the length of the maxillae.
c. Cephalic row of spines on second abdominal segment lacking
the female; cremastral setae noticeably flattened.
Platynota **Clemen**
cc. Cephalic row of spines on the second abdominal segment prese
in the female; cremastral setae not noticeably flattened.
Epagoge **Hübne**
bb. Cremaster broader than long, distinctly flattened; labial palpi n
more than half the length of the maxillae..*Archips* (b) Hübne

The following species were examined:
Harmologa fumiferana Clemens
Archips (a) *argyrospila* Walker, *magnoliana* Fernald, *parallela* Robi
son, *obsoletana* Walker, *rosaceana* Harris
Archips (b) *cerasivorana* Fitch, *fervidana* Clemens
Cenopis chambersana Kearfott
Phaecasiophora confixana Walker
Platynota flavedana Clemens
Epagoge sulfureana Clemens

Superfamily GRACILARIOIDEA

This superfamily name is given to a number of families apparent
of common origin, which have proceeded along similar lines of deve

opment. The species are all leaf-miners and are very small, the pupae of the largest species examined being 7 mm. in length. Very few of the generalized families have been available for study, so that it is exceedingly difficult to trace the relationships existing between the more specialized families without first having carefully studied a number of more generalized forms. There is included in this group the Nepticulidae, in many respects the most generalized pupae studied, next to the Eriocraniidae, and certainly resembling the latter more than any of the other generalized forms examined. It is just at this point in our investigation that more material is needed to clear up the relationships of the groups which have apparently branched off here and have had a common ancestor with the Nepticulidae. From all the evidence at hand it seems probable that development has proceeded along two well-defined lines, the first, represented by the superfamily Gracilarioidea, having early lost the maxillary palpi while still retaining the covering of spines on the dorsum of the abdominal segments, and having developed the triangular type of prothorax; the second having retained the maxillary palpi for a much longer time, but having lost the covering of spines, while developing the same type of prothorax.

Of the second type no material has been examined which would show any intermediate stages between the families Nepticulidae and Epermeniidae. The latter family has apparently continued the line of development begun in the Gracilarioidea as it still retains the seventh abdominal segment free in the male though it is fixed in the female. The presence of the maxillary palpi precludes its derivation from the Gracilarioidea and would lead us back to some point below the Heliozelidae because this family also has lost them. As we have only the Nepticulidae for comparison, it has been assumed that this branch has arisen coordinately with them.

In the superfamily Gracilarioidea, with the exception of the family Lyonetiidae, all the pupae have free appendages, the cuticle is very slightly chitinized, and the dorsum of the abdomen is covered, in part at least, with fine spines. There is a tendency in some genera, as Lithocolletis and Ornix, towards the development of a single row of spines, so that there is often one or more rows of larger spines at either the cephalic or caudal margin, or at both margins, of the segment. This seems to indicate the way in which the rows of spines were developed in the Tineoidea and Tortricoidea. The characters which are common to all the members of the superfamily are the long vertex, which is always longer than the prothorax at the median line, scarcely ever less than twice its length and often much longer, and the long

metathorax, with the loss of a well-developed maxillary palpus in families above the Nepticulidae. Chapman described the genus Gracilaria as possessing maxillary palpi, and in two species, *sassafrasella* and *negundella,* a structure has been found (Figs. 45, 47) which may be the maxillary palpus; but there never is a distinct, oblong piece lying caudad of the eye-piece as is usually the case when the maxillary palpi are present, and of all the species of the superfamily examined these two were the only ones in which there was any doubt as to its absence. The head is in most families either produced into a prominent projection or there is a heavily chitinized cutting plate near the cephalic margin on the ventral surface. The prothorax has a tendency to become shorter on the median line and longer on its lateral margins, so that each half is triangular. In such cases the length along the lateral margin is about four times the length on the median line. In the more generalized forms the prothorax is more like the rectangular type found in the Tineoidea, but it is depressed or sunken, giving it a neck-like appearance. The metathorax still retains its primitive condition, and is usually more than half the length of the mesothorax. In nearly all of the families the wings are long in proportion to the body, and in the majority they are about two thirds its length. The bodies of most of the families included here retain the generalized type found in the Eriocraniidae with a slight depression near each lateral margin in the region of the spiracles. The spiracles are usually small, circular, and slightly produced, appearing tubular. The Lyonetiidae seem to be an exception to almost every rule. They have no free segments, the appendages are all soldered to the body, and there are no spines visible on the abdomen. They seem to be more nearly related to the Bucculatrigidae than to any other family, although there are strong reasons for considering them related to the Phyllocnistidae. The following table will serve to separate the families of Gracilarioidea:

a. Maxillary palpi well developed and extending along the caudal margin of the eye; spiracles visible on the first abdominal segment.
NEPTICULIDAE.

aa. Maxillary palpi never well developed, and if present never extending as an oblong piece along the caudal margin of the eye.

b. Antennae never extending more than half the length of the wings; labrum very long and lobe-like, extending down over the labial palpi for about one fourth of their length; spines on the dorsum of the abdomen very fine and not easily distinguished.
HELIOZELIDAE.

bb. Antennae always extending at least three fourths the length of the wings, and usually equaling them in length or extending beyond their caudal margin; labrum never long and lobe-like and never

extending down over the labial palpi for one fourth of their length.

c. Appendages free, never firmly soldered to the body wall; abdomen always with some of the segments movable; dorsum of the abdomen always with spines.

d. Abdominal segments 3–7 movable in the male, 3–6 in the female; antennae and metathoracic legs not approximately equal in length and both seldom extending beyond the caudal margin of the wings.

e. Labial palpi present; caudal end of body ending in two stout spines directed dorsad; abdominal segments 3–6 with the two setae nearest the meson on the cephalic half of the segment so closely approximated that their bases touch. TISCHERIIDAE.

ee. Labial palpi never visible; caudal end of body never with curved hooks, but the tenth abdominal segment with a prominent lateral projection on each side ending in a stout straight spine; abdominal segments 3–6 with the setae nearest the meson at the cephalic end of the segment never closely approximated ..... BUCCULATRIGIDAE.

dd. Abdominal segments 4–7 movable in the male, 4–6 in the female; antennae and metathoracic legs approximately of equal length and both always extending beyond caudal margin of the wings.

e. Abdominal segments 3–7 never with two deep punctures or pits with heavily chitinized edges on the meson at the cephalic margin with one or more heavily chitinized spines adjacent; the length of abdominal segments 8–10 always greater than that of segment 7..... GRACILARIIDAE.

ee. Abdominal segments 3–7 with two deep punctures on the meson at the cephalic margin with one to three heavily chitinized spines adjacent; abdominal segments 8–10 never showing distinct segmentation, their total length less than that of the seventh segment..... PHYLLOCNISTIDAE.

cc. Appendages always firmly soldered to the body; dorsum of abdomen without visible spines; abdomen without any movable segments ..... LYONETIIDAE.

Family NEPTICULIDAE

These tiny species of leaf-miners average 2 mm. in length in the females and 1.5 mm. in the males. The body is flattened, with a transparent, slightly chitinized cuticle, and is white in color until the adult scales are formed. Although their size makes it difficult to determine the number of free segments, it is believed that there is some degree of motion between all of the abdominal segments except the fixed

caudal ones. There is some degree of movement between the seventh and eighth abdominal segments in both sexes, but it is apparently greater in the male. The arrangement of parts may be seen in Figures 48 and 49. The head does not show all of the sutures found in the Eriocraniidae, but the epicranial and fronto-clypeal sutures are always present. The appendages are all free and segmented as in the Eriocraniidae, and the thoracic appendages are widely separated to show all the coxae. There is a strong resemblance between this family and the more generalized members of the Eucleoidea, but the presence of the large maxillary palpi prevents their being included in that superfamily. The spiracles are visible on the first abdominal segment, and the length of the thoracic segments indicates a very generalized condition. The genital opening of the male is located as shown in Figure 48. In the females there is an area covered with setae on the venter of the eighth segment, as in the Eriocraniidae, but no openings could be accurately determined.

The following species were examined:
Nepticula nyssaefoliella Chambers, *platanella* Clemens.

Family Heliozelidae

This family includes some very small pupae which measure only 2–3 mm. in length. They have all the appendages free and widely separated. The cuticle is transparent and the body white in color, with the conjunctiva so little differentiated that it was impossible to determine the number of free segments with accuracy. Segments 2–7 in the male and 2–8 in the female have some power of motion, but whether this is movement of the whole segment in the case of the second and third, or merely dorsal movement, was not determined. The family (Fig. 50) is characterized by its short antennae, and its long labrum which projects down over the labial palpi. They also have shorter appendages than any of the other families with transparent cuticle and white bodies, because in all others the metathoracic legs and antennae extend considerably beyond the caudal margin of the wings and are often longer than the body. The epicranial suture is near the cephalic margin of the head. While this family may have retained more free segments than the Gracilariidae it is undoubtedly more specialized than some of the genera in that family. The prothorax is much longer at its lateral margins than on the meson; there is no trace of maxillary palpi, and the labial palpi are not so well developed as in the generalized Gracilariidae.

The genera included in this family have long been associated with the Elachistidae, but the pupae show no resemblance whatever to this

family. The name Heliodinidae has been applied by some authors to the genera included in this family, but Meyrick, in Lepidoptorum Catalogus, Part 13, uses this name to include the genera Brenthia, Choreutis, etc. The name Heliozelidae is used by Spuler (Die Schmetterlinge Europas, 1910) and this name has been adopted there. The genera may be separated as follows:

a. Abdomen with one or two prominent lateral setae on each side of the tenth abdominal segment; mesonotum not produced into a prominent lobe extending down on the metathorax.....*Antispila* Hübner.

aa. Abdomen never with prominent lateral setae on each side of the tenth abdominal segment; mesonotum produced into a prominent lobe extending down on the metathorax.....*Coptodisca* Walsingham.

The following species were examined:
Antispila ampelopsisella Chambers, *cornifoliella* Clemens
Coptodisca juglandiella Chambers, *splendiforella* Clemens

Family Tischeriidae

These pupae are from 3.5–6 mm. in length and have abdominal segments 3–7 free in the male and 3–6 in the female. They are always considerably chitinized, so that the pupae vary in color from yellow to brown. The spines on the dorsum of the abdominal segments are very distinct and in some species they are of two sizes. All of the species examined except *Tischeria heliopsisella* (Fig. 54) had certain of the body setae very long, heavily chitinized, and forked at the end. These setae vary in length, but the shortest are nearly as long as the abdominal segments and are very conspicuous. The dorso-mesal setae nearest the cephalic margin were closely approximated on segments 3–6 or 7 of the abdomen so that their bases were in contact. The caudal end of the abdomen is bifurcate, and ends in two heavily chitinized hooks which are directed dorsad. The arrangement of parts may be seen in Figures 51–54. These pupae have become more specialized in certain respects than many of the Gracilariidae, although they retain one more free segment. This is noticeable in the development of the prothorax, in the distinct rows of larger spines on many of the segments, and in the strong caudal hooks. The fronto-clypeal suture shows as a clear area, indicated by the dotted line in Figure 51. This family includes two genera, Coptotriche and Tischeria, with no well-defined characters for separating them. The two species of Tischeria, *aenea* from blackberry and *malifoliella* from apple, at one time considered identical, show distinct differences in the pupae and both species resemble Coptotriche, while *heliopsisella* is very different from all the

rest. Dyar's list names but one species of Coptotriche, but three distinct types of pupae have been obtained from mines in oak leaves. Unfortunately no adults have yet emerged from these, so the species can not be determined. The genera may be separated as follows:

a. Caudal margin of the dorsum of the second abdominal segment heavily chitinized and toothed, the teeth being larger than the adjoining spines ..... *Coptotriche* Walsingham.

aa. Caudal margin of the dorsum of the second abdominal segment not heavily chitinized or toothed ..... *Tischeria* Zeller.

The following species were examined:

Coptotriche zelleriella Clemens

Tischeria aenea Frey and Boll, *malifoliella* Clemens, *heliopsisella* Chambers

Family Bucculatrigidae

This family, Bucculatrigidae, including the single genus Bucculatrix, has been placed in various positions by different authors. It is quite evident that it is more specialized than most other families of the Gracilarioidea in the loss of the labial palpi and that it has proceeded along a different line of development. Nevertheless, no one can fail to see the relationship between the pupae of the Bucculatrigidae and the other members of this superfamily, particularly to some of the species of Cameraria where there is a lateral projection from each side of the tenth segment and a distinct row of larger spines on the dorsum of the abdominal segments. The lack of labial palpi, together with the spines on the abdominal segments, is sufficient to distinguish the family from all the others included in the superfamily. The arrangement of parts may be seen in Figures 55 and 56. The pupae examined had an average length of 3 mm.

The following species were examined:

Bucculatrix sp., *pomifoliella* Clemens, *trifasciella* Clemens.

Family Lyonetiidae

This family is a very difficult one to place satisfactorily by pupal characters alone, as it has completely lost the power of motion in the abdominal segments and all the appendages are soldered down. This is another of the families which has been a source of anxiety to many lepidopterists. The shape of the prothorax, the length of the vertex, together with that of the wings and appendages as compared with the body, the small tubular spiracles, and the absence of maxillary palpi seem without any doubt to indicate its relationship to the members of the superfamily Gracilarioidea and consequently it is included here.

From a careful study of the pupal characters available it seems to be more nearly related to the Bucculatrigidae than to any other family. A comparison of Figure 57 or 59 with 67 will show that the development in the Lyonetiidae has not been towards the shortening of the segments and the consolidation of abdominal segments 8–10 as in the Phyllocnistidae. Moreover, it still retains the generalized type of body found in the Nepticulidae, while the Phyllocnistidae have developed the cylindrical type. The shape of the maxillae and the position of the femur of the prothoracic leg are as in the Bucculatrigidae, and like them the Lyonetiidae have no labial palpi visible. The Lyonetiidae do not spend their pupal life within the mine, nor in a cocoon, but are exposed and fixed by the caudal end to some cross threads on the under surface of the leaf (Clemens, Tineina of N. America, 1872, pp. 189–191). The soldering down of the appendages and the loss of motion of the abdominal segments seems to be a modification to suit the new conditions of life, and is analogous to the condition found in certain families of Papilionoidea and the species of the genus Elachista, in which all power of motion is lost. Bedellia has developed certain ridges and projections, similar to those found in the Papilionoidea, which seem to be correlated with this manner of pupal life. Only two genera of Lyonetiidae were studied. These were from 4–6 mm. in length and may be separated as follows:

a. Head blunt, without a prominent projection; antennae and metathoracic legs equal in length; caudal end of body with a few straight spines on the dorsal surface of the tenth abdominal segment: body without prominent ridges.....*Proleucoptera* Busck.

aa. Head with a long projection; antennae much longer than the metathoracic legs; caudal end of body with hooked setae; body with prominent ridges.....*Bedellia* Stainton.

The following species were examined:
Proleucoptera smilaciella Busck
Bedellia somnulentella Zeller

Family Gracilariidae

This large family includes those pupae with free appendages and with abdominal segments 4–7 free in the male and 4–6 in the female. The antennae and metathoracic legs are of approximately the same length and both are longer than the wings. The most nearly related family, the Phyllocnistidae, differs in having on the dorsum of each abdominal segment two prominent pits or punctures with heavily chitinized edges associated with some large curved spines, in having

a much more cylindrical body with large deep furrows between the segments, and in having the fixed caudal segments very short.

The genus Gracilaria is undoubtedly the most generalized, if we consider the peculiar structures (Fig. 47) found in some species to be maxillary palpi. The tendency in the Gracilariidae is toward the loss of the maxillary palpi, and the development of the triangular type of prothorax, which usually is elevated on the median line. There is also a shortening of the maxillae and labial palpi and of all the appendages in relation to the rest of the body, and a stronger chitinization of the surface of the body tending to a soldering down of the appendages. There is also taking place the development of two sizes of spines on the dorsum of the abdominal segments and the formation of single rows of larger spines. Finally there is the development of the cremaster. There are two distinct divisions of the Gracilariidae to which subfamily names have been given. These may be separated as follows:

a. Prothorax depressed and neck-like, somewhat quadrangular in outline, the length at the lateral margin never more than twice the mesal length ..... GRACILARIINAE.

aa. Prothorax usually with an elevated ridge on the meson, triangular in outline, the length at the lateral margin about four times the mesal length ..... LITHOCOLLETINAE.

Subfamily *Gracilariinae*

The Gracilariinae (Figs. 45 and 46) include all the genera in which the generalized quadrangular type of prothorax has been retained. In all the genera the caudal end of the body is blunt and the tenth segment bears a row of 6 or 8 spines, larger than those on the other body segments. The labial palpi are always long and never covered by the maxillae at their proximal end. The following table will serve to separate the genera of Gracilariinae:

a. Dorsum of abdomen sparsely covered with very coarse spines, sometimes with additional fine spines.
   b. Head with a cutting plate on the ventral surface near the cephalic margin, which is usually serrate; maxillae as long as the mesothoracic legs ..... *Gracilaria* Haworth.
   bb. Head with a prominent projection at the cephalic end, not a distinct plate; maxillae never as long as the mesothoracic legs. *Ornix* Treitschke.

aa. Dorsum of abdomen thickly covered with very fine spines which are almost invisible ..... *Parectopa* Clemens.

Subfamily *Lithocolletinae*

In the Lithocolletinae all the genera but Acrocercops have a strongly elevated median ridge on the prothorax, and in all but Acrocercops and Marmara the proximal part of the labial palpi is covered by the maxillae so that the lateral margin can not be traced cephalad to the labrum. The genus Lithocolletis, which seems very distinct from other genera in the subfamily, includes two distinct types of larvae. On this basis the genus was divided into two groups designated as the "flat-larval group" and the "cylindrical-larval group." Dr. Chapman in 1902 (Entomologist, Vol. 35, p. 141) proposed the name Cameraria for the flat-larval group, and this name is used here as our investigation shows that the cremaster is a decided genus character, and, furthermore, that members of the same genus have the same type of cremaster. It is therefore deemed impossible, from a study of the pupal characters, that one genus could include both forms with and without a cremaster. The pupae of the cylindrical-larval group studied, moreover, showed two distinct types of cremaster, *L. lucidicostella* (Fig. 66a) having a rather broad cremaster with curved setae, while in *L. tiliacella* and *L. argentinotella* the cremaster is long and slender (Figs. 66b and 64) and the setae are T-shaped, the former having one such seta and the latter two. From the standpoint of pupal characters these would properly form three genera. It is interesting to note that Meyrick (Genera Insectorum, Part 128) places these in different sections of the genus, and that Miss A. F. Braun in her work on the "Development of the Color Pattern in Lithocolletis" (Journ. Acad. Nat. Sci. Phila., Vol. 16, Series 2, 1914) also includes them as members of different groups in her phylogenetic tree. The genera of Lithocolletinae may be separated as follows:

a. Dorsum of abdominal segments with spines of the same size; caudal margins of abdominal segments never distinctly elevated.
  b. Dorsum of each abdominal segment covered with spines for its entire length.
    c. Maxillae at least seven eighths the length of the wings; labial palpi almost half the length of the maxillae, their proximal end not covered by the maxillae; spines on dorsum of abdomen very small and inconspicuous except a row of six spines on the tenth segment..... *Acrocercops* Wallengren.
    cc. Maxillae not more than one third the length of the wings; labial palpi about one third the length of the maxillae, their proximal end covered by the maxillae; spines on the dorsum of the abdomen small but distinct, with a few larger ones on the tenth segment..... *Leucanthiza* Clemens.

bb. Dorsum of each abdominal segment covered with spines for about one fourth its length.

c. Head without a prominent pointed projection; maxillae more than half the length of the wings and longer than the prothoracic legs; proximal part of the labial palpi not covered by the maxillae.....*Marmara* Clemens.

cc. Head with a prominent projection; maxillae never half the length of the wings nor as long as the prothoracic legs; labial palpi covered by the maxillae at the proximal end.
Cremastobombycia Braun.

aa. Dorsum of abdominal segments covered with spines of two sizes, the caudal margins of the segments usually distinctly elevated; labial palpi always covered by the maxillae at the proximal end.

b. Caudal end of body never with a distinct cremaster.
Cameraria Chapman.

bb. Caudal end of body always with a distinct cremaster.
Lithocolletis Hübner.

Species of Gracilariidae examined:

Subfamily Gracilariinae

Gracilaria negundella Chambers, *sassafrasella* Chambers, *violacella* Clemens

Ornix prunivorella Chambers, *crataegifoliella* Clemens, *conspicuella* Dietz

Parectopa salicifoliella Chambers, *lespedezaefoliella* Clemens

Subfamily Lithocolletinae

Acrocercops venustella Clemens

Leucanthiza amphicarpeaefoliella Clemens, *ostensackenella* Fitch

Marmara salictella Clemens

Cremastobombycia solidaginis Frey and Boll

Cameraria hamadryadella Clemens, *ostryella* Chambers, *tubiferella* Clemens

Lithocolletis lucidicostella Clem., *argentinotella* Clemens, *tiliacella* Chambers

Family Phyllocnistidae

This family is very nearly related to the Gracilariidae, and the principal characters used to distinguish it are given under that family. The arrangement of parts may be seen in Figure 67. It will be noted that Phyllocnistis has long heavily-chitinized setae much as in the Tischeriidae except that they are not forked at the tip. There is a fleshy prolongation on each side of the tenth abdominal segment. This family shows a somewhat higher degree of specialization in the prothorax and labial palpi than most of the Gracilariidae. It is, however, not as much specialized as the species of Lithocolletis which have de-

veloped a cremaster, but is more like Cameraria. It may have been developed from the same stem as Cameraria, but its development is more likely to have been parallel with that of the family Gracilariidae. The body is considerably more chitinized, however, than in any member of that family. This family includes a single genus, Phyllocnistis Zeller, in which the pupae are from 3–4 mm. in length.

The following species were examined:
Phyllocnistis ampelopsisella Chambers, *insignis* Frey and Boll.

Specialized pupae with pilifers

There are two superfamilies of Lepidoptera, the Pyralidoidea and the Papilionoidea, in which the pilifers are enormously developed, and their presence is indicated in the pupa by lobes which extend from the caudo-lateral angles of the labrum towards the meson and in many instances are adjacent on the meson (Figs. 70, 72, 74, 76, 79; pf). Besides the presence of these lobes there are many other points of resemblance which would seem to indicate that these two superfamilies had a common ancestor.

Superfamily PYRALIDOIDEA

This superfamily includes all those pupae which possess lobes indicating the presence of well-developed pilifers and which do not possess clubbed antennae. This comprises the family Pterophoridae, the family Attevidae, previously included in the Yponomeutidae, and probably all of the subfamilies of Pyralididae, although pupae of only six of these were examined. The Gallerinae do not possess the lobes indicating the presence of pilifers, and differ in many other respects from most other pyralids.

The antennae are long, at least five sixths the length of the wings, and in some instances extend beyond them. The maxillae and mesothoracic legs are both long and extend to the caudal margin of the wings in most genera. The femora of the prothoracic legs are visible except in some genera of Pterophoridae. In all of these families the appendages are soldered to each other and to the body wall, but in the Pterophoridae they are very slightly soldered and separate readily. The seventh abdominal segment is free in the males of Pterophoridae and Attevidae but fixed in the female. In the Pyralididae it is fixed in both sexes. The families of Pyralidoidea may be separated as follows:

a. Maxillary palpi never present; the prothoracic and mesothoracic legs always extending cephalad between the sculptured eye-piece and the antennae; body always roughened with short spines or with small

groups of long barbed spines and setae arising from small elevations; dorsum of abdomen never with a deep furrow between the ninth and tenth segments.....PTEROPHORIDAE.

aa. Maxillary palpi usually present, if not, then the dorsum of the abdomen with a deep furrow between the ninth and tenth segments; body surface seldom roughened with spines or setae.

b. Epicranial suture never present; fronto-clypeal suture visible for about half the distance between the proximal end of the antennae and the meson; seventh abdominal segment free in the male and fixed in the female; dorsum of abdomen never with a furrow between segments nine and ten.....ATTEVIDAE.

bb. Epicranial suture usually present, if not, then the dorsum of the abdomen with a deep furrow between the ninth and tenth segments; fronto-clypeal suture never indicated; seventh abdominal segment fixed in both sexes.....PYRALIDIDAE.

Family PTEROPHORIDAE

This family possesses a curious combination of generalized and specialized characters which make its position rather difficult to determine. It has lost the maxillary palpi, the femora of the prothoracic legs are seldom visible, and the epicranial suture is present in but one genus, Pterophorus, where only a small portion of it is visible. On the other hand the seventh abdominal segment is free in the male and fixed in the female. This is clearly seen at dehiscence, for none of the abdominal segments possess much power of motion. The appendages (Fig. 70) are only slightly soldered to each other and to the body wall, and generally separate very readily. The wings are slender and pointed and, together with the other appendages, project slightly beyond the margin of the fourth abdominal segment. The clypeus, labrum, and sculptured eye-piece each bear two prominent setae in Pterophorus and Oxyptilus but in Platyptilia they are very small. There is usually a seta near the caudal margin of each gena. The proximal portion of each antenna is usually considerably widened and ridged and in Pterophorus and Oxyptilus bears long spines. The prothoracic legs are exceptionally long in this family and reach nearly to the caudal margin of the wings. The maxillae are often overlaid by the prothoracic legs for a part of their length, and sometimes are only visible for a short distance at their proximal and distal ends, the entire mesal portion being concealed. The location of the genital openings is unusual, appearing to be always on the tenth abdominal segment, which extends very far cephalad and forms a sort of ventral plate on the fixed caudal segments. In Platyptilia the plate is not so prominent and the dividing sutures between the segments may be dis-

tinguished. At the cephalic margin of this plate is a large group of hooked setae in Pterophorus and Oxyptilus, and in Platyptilia a rounded tubercle bearing four hooked setae. The abdominal spiracles are slightly produced. The mesothoracic spiracle is situated mesad of its usual position. It is also slightly produced. The peculiar spiny armature of most of the genera makes them very easy to distinguish from all other pupae. They are always found exposed, attached by the cremaster, and vary in length from 8–15 mm. The genera may be separated thus:

a. Body with long, prominent barbed spines and setae arising mostly from dorsal and lateral elevations; tenth segment with a mass of hooked setae at its cephalic margin.
   b. Femora of the prothoracic legs exposed; dorsal and lateral elevations with barbed spines of varying lengths.
      Pterophorus Geoffroy.
   bb. Femora of the prothoracic legs never exposed; dorsal and lateral elevations usually with two barbed spines which are very broad at base and on the side of each is inserted a stout straight seta.
      Oxyptilus Zeller.
aa. Body without any long barbed spines or setae, but with short, widely separated triangular projections on most of the abdominal segments; tenth segment with a rounded prominence near the cephalic margin bearing about four hooked setae.....*Platyptilia* Hübner.

The following species were examined:
Pterophorus paleaceus Zeller
Oxyptilus tenuidactylus Fitch
Platyptilia carduidactyla Riley

Family Attevidae

The genus Atteva (Figs. 72, 73), formerly included in the family Yponomeutidae, was found to differ in all its important characters from the members of that family and to be closely allied to the Pyralididae. It retains the same arrangement of setae on the clypeus and labrum as that in the Yponomeutidae. The setae at the caudal end of the body are also similar in arrangement to those in theYponomeutidae, but the subfamily Phycitinae also have setae arranged in this way. It seems very probable that the Attevidae and Yponomeutidae arose from a common stock, but that the former branched off before motion was lost in the seventh segment of the male. In the Attevidae there is a narrow conjunctiva between the seventh and eighth segments in the male and there is slight motion possible. The eighth, ninth, and tenth segments are unusually long and distinctly segmented. There is

no epicranial suture present, and at dehiscence the eye-pieces are not separated from the other face-parts, which indicates a high degree of specialization. The maxillary palpi are present, but not as well developed as in most pyralids. The labial palpi are represented by a small polygonal area caudad of the lobes indicating the presence of pilifers which meet on the meson. The fronto-clypeal suture is present for about half the distance between the proximal ends of the antennae and the meson and it dehisces for this distance at the emergence of the imago. This family includes the single genus Atteva. The pupae of this family are from 15–20 mm. in length.

The following species was examined:
Atteva aurea Fitch.

Family Pyralididae

This family (Figs. 74, 75, 76) includes a number of subfamilies, of which only six are discussed here. The epicranial suture is present in all of these except the Epipaschiinae and a few genera of Phycitinae but the vertex is very short in all of the others, and often represented by a small triangular area, adjacent to each antenna, which does not reach to the meson. The antennae are long, at least seven eighths the length of the wings and often much longer, and the distal ends never meet on the meson. The labial palpi are visible only as small triangular or polygonal areas except in the Crambinae, which often show a large portion between the halves of the maxillae. The maxillae are always long except in the Gallerinae, usually reaching the caudal margin of the wings and sometimes extending beyond them. The maxillary palpi are present in all subfamilies except the Epipaschiinae. Each prothoracic leg is from one half to three fourths the length of the wings and its femur is always exposed. The mesothoracic legs generally extend to the caudal margin of the wings. The abdominal segments never possess spines except in the Gallerinae but are smooth or punctate. The spiracles are of different types, some being slightly produced. The location of the mesothoracic spiracle is difficult to determine in most species, there being no visible opening. The appendages are always firmly soldered to each other and the body wall. The pupae vary in length from 8–20 mm. The following table will serve to separate the subfamilies of Pyralididae:

a. Maxillary palpi always present; epicranial suture usually distinct, at least for a part of its length.
  b. Maxillae never more than three fifths the length of the wings; dorsum of thorax and abdomen with a prominent median ridge and the segments covered with small spines..... Gallerinae.

bb. Maxillae always more than three fifths the length of the wings; dorsum of thorax and abdomen never with a median ridge or with small spines on the segments.

c. Cremaster absent or never long and well developed; furrows usually present on the dorsum between the ninth and tenth abdominal segments, or on the lateral part of the tenth segment; head usually rounded; body never with a shouldered appearance; labrum in its normal position.

d. Caudal end of body with all the setae straight and very short; cremaster short and blunt; lateral margins of the dorsum of tenth abdominal segment with prominent deep furrows extending caudad to the proximal end of the cremaster; a large portion of the labial palpi often exposed ..... CRAMBINAE.

dd. Caudal end of body never with all the setae straight, but usually long and hooked; lateral margins of the tenth abdominal segment never with deep furrows unless they are extensions of the dorsal furrow between the ninth and tenth segments; labial palpi never with more than a very small triangular or polygonal area exposed.

e. Dorsal furrow, if present between the ninth and tenth abdominal segments, with a crenulate margin; mesothoracic spiracles never tubular, but slit-like and not plainly indicated; caudal end of body without a cremaster, and bearing a transverse row of six or eight slender hooked setae..... PYRALINAE.

ee. Dorsal furrow usually present between the ninth and tenth abdominal segments but never with a crenulate margin, if the dorsal furrow is absent then the mesothoracic spiracles produced and tubular; cremaster wanting or very short..... PHYCITINAE.

cc. Cremaster always present and well developed; dorsal furrows never present between the ninth and tenth abdominal segments or on the lateral part of the tenth segment; head blunt; body with a distinctly shouldered appearance; labrum always cephalad of its normal position..... PYRAUSTINAE.

aa. Maxillary palpi never present; epicranial suture never visible for any part of its length; dorsal furrow between the ninth and tenth abdominal segments strongly curved caudad and apparently lined with a fringe of short setae..... EPIPASCHIINAE.

Subfamily *Gallerinae*

The pupae of this subfamily are very different from most pyralids and there is some doubt as to whether they should be included with

this family. The lobes which indicate the presence of pilifers are n well developed and the maxillae are short (Fig. 69). The body short and thick and covered on the dorsum of the thorax and abd men with short spines. A strongly elevated median ridge is al present on the thorax and on the first eight abdominal segments. Tl prothorax is very long, at least half the length of the mesothorax.

The following species was examined:

Galleria melonella Linnaeus.

Subfamily *Crambinae*

The pupae of the Crambinae are easily recognized by the peculi form of the short, blunt cremaster and the deep lateral grooves on tl tenth abdominal segment. Some of the species show a large portic of the labial palpi, indicating that this subfamily is one of the mo generalized. The maxillae reach almost to the caudal margin of tl wings and the tips of the mesothoracic legs meet on the meson ju caudad of the maxillae. The segments are almost smooth, nev punctate.

The following species were examined:

Crambus vulgivagellus Clemens, *trisectus* Walker, *caliginosellus* Cler ens.

Subfamily *Pyralinae*

The species of this subfamily resemble closely the genera Plod and Ephestia of the Phycitinae. There scarcely seems to be more tha generic differences between them. The epicranial suture is prese and the vertex always extends to the meson. The maxillary palpi a well developed and usually reach the proximo-lateral angles of tl maxillae. There is never a cremaster present, but a transverse row hooked setae at the caudal end of the body. The two genera studi may be separated as follows:

a. Dorsum of abdomen with a furrow between the ninth and tenth se ments, the caudal margin of the furrow distinctly crenulate. ***Pyralis*** **Linnaeu**

aa. Dorsum of abdomen without a furrow between the ninth and ten segments..... ***Hypsopygia*** **Hübne**

The following species were examined:

Pyralis farinalis Linnaeus

Hypsopygia costalis Fabricius

Subfamily *Phycitinae*

This group is, for the most part, easily distinguished from other pyralids by the presence of the suture on the dorsum of the abdomen between the ninth and tenth segments, the presence of maxillary palpi, and, usually, of the epicranial suture. Of the genera examined, Ephestia and Plodia alone were without this dorsal furrow, and they possess tubular spiracles on the mesothorax. These two genera seem rather more closely related in many respects to the Pyralinae than to the Phycitinae. The maxillary palpi always extend to the proximo-lateral angles of the maxillae, and the epicranial suture is present in all genera examined but Pinipestis and Mineola, though it is very near to the suture between the head and prothorax. The vertex is usually represented by a small triangular area adjacent to each antenna. The lobes enclosing the pilifers meet on the meson in some genera. The genera of Phycitinae may be separated as follows:

a. Dorsal surface without a prominent furrow separating the ninth and tenth abdominal segments; mesothoracic spiracles tubular.
  b. Abdominal segments punctate; maxillae reaching the caudal margin of the wings.....*Ephestia* Guenée.
  bb. Abdominal segments smooth; maxillae never reaching the caudal margin of the wings.....*Plodia* Guenée.
aa. Dorsal surface with a prominent furrow separating the ninth and tenth abdominal segments; mesothoracic spiracles never tubular, their exact position usually difficult to determine.
  b. Body depressed; tenth abdominal segment with the caudal end distinctly margined and with six straight setae inserted on the ventral side of the margin.....*Acrobasis* Zeller.
  bb. Body never depressed; tenth abdominal segment never with the caudal end distinctly margined or with setae inserted on the ventral side of the margin.
    c. Caudal end of body with four long hooked setae, and on each side of these a short spine or hooked seta extending laterad.
      d. Tenth abdominal segment with lateral spines very different from the caudal setae.
        e. Ninth abdominal segment with a lateral spine on each side similar to those on the tenth segment, and two hooked setae on the dorsum adjacent to the caudal margin; caudal hooked setae equidistant...*Mineola* Hulst.
        ee. Ninth abdominal segment without lateral spines or hooked setae on the dorsum adjacent to the caudal margin.
          f. Caudal spines not adjacent; equidistant; of equal length .....*Meroptera* Grote.

ff. Caudal spines adjacent; two of them shorter than the other two.....*Psorosina* Dyar.
dd. Tenth abdominal segment with lateral hooked setae similar to the caudal setae.....*Canarsia* Hulst.
cc. Caudal end of body with a transverse row of six long hooked setae of equal length; epicranial suture never present; head with a prominent pointed cephalic projection.
Pinipestis Grote.

The following species were examined:
Plodia interpunctella Hübner
Ephestia kuehniella Zeller
Acrobasis rubrifasciella Packard
Mineola indiginella Zeller
Meroptera pravella Grote
Psorosina hammondi Riley
Canarsia ulmiarrosorella Clemens
Pinipestis zimmermani Grote

Subfamily *Pyraustinae*

This group is distinguished by the peculiar "shouldered" appearance of the body, caused by the great width of the thorax as compared with the head and by the position of the labrum, which is always cephalad of its normal position and often located near the cephalic end of the body. There is never a furrow on the dorsum between the ninth and tenth abdominal segments. The maxillary palpi are always present and only a very small portion of the labial palpi is exposed. The epicranial suture is present in all genera. The mesothoracic legs and antennae, together with the metathoracic legs which are hidden by them, usually extend beyond the caudal margin of the wings. The mesothoracic spiracles often have peculiar ridges along their caudal margin which are sometimes covered with setae. Similar ridges are found in certain families of Papilionoidea and Notodontoidea. The shape of body and arrangement of parts in the Pyraustinae resembles that of certain Sphingidae, and would seem to indicate that the Pyraustinae are not as closely related to the Phycitinae as the other subfamilies, which all show a very close relationship. The genus Pyrausta as understood at present probably does not represent a natural group. Of the species studied *P. fissalis* and *P. illibalis* have long narrow cremasters of similar type, while *P. futilalis* and *P. inæqualis* have short broad cremasters of rather different types. There is also great variation in the length of the appendages, but this is not such a decided generic character as the form of the cremaster. This

subfamily includes the largest pyralids examined. The genera of Pyraustinae may be separated by the following table:

a. Setae of the cremaster always hooked and equal in length to the cremaster or sometimes longer; the other appendages never extending beyond the caudal margin of the wings.
  b. Setae of the thorax and abdomen very long, heavily chitinized, and forked at the distal end, usually much longer than the segments; mesothorax and metathorax having a deep oblong pit with strongly chitinized edges at the base of each wing. *Phlyctaenia* Hübner.
  bb. Setae of the thorax and abdomen never prominent, scarcely ever visible; mesothorax and metathorax never having a deep oblong pit at the base of each wing.
    c. Mesothoracic spiracle with a prominent elevation adjacent to the caudal margin, which bears several ridges fringed with setae; front with a distinct tubercle or small ridge at the base of each antenna..... *Desmia* Westwood.
    cc. Mesothoracic spiracle without any prominent elevation adjacent to the caudal margin; front without a tubercle or ridge at the base of each antenna..... *Pantagrapha* Lederer.
aa. Setae of the cremaster either straight and equal in length to the cremaster, or hooked and much shorter than the cremaster; the other appendages often extending beyond the caudal margin of the wings.
  b. Prothorax with a distinct tubercle on each side of the meson; cremastral setae straight and spread out fan-like. *Tholeria* Hübner.
  bb. Prothorax without a distinct tubercle on each side of the meson; cremastral setae hooked, and not spread out fan-like. *Pyrausta* Schrank.

The following species were examined:
Phlyctaenia ferrugalis Hübner
Desmia funeralis Hübner
Pantagrapha limata Grote and Robinson
Tholeria reversalis Guenée
Pyrausta fissalis Grote, *illibalis* Hübner, *futilalis* Lederer, *insequalis* Guenée

Subfamily *Epipaschiinae*

Only one species of this group has been examined, so no very definite statements can be made regarding it. The species examined seems to differ mainly in the absence of the maxillary palpi, which are present in all of the other subfamilies. The epicranial suture is not visible and the labrum is slightly cephalad of its normal position. The dorsum of the abdomen shows a decided furrow between the ninth

and tenth segments which is strongly curved caudad and apparently covered with some fine whitish setae, but this appearance may be due to the fine striations present. The caudal margin of the furrow is crenulate. There is a very short cremaster present, bearing a small group of hooked setae, which are more than half as long as the tenth segment.

The following species was examined:
Lanthape platanella Clemens.

Superfamily PAPILIONOIDEA

The members of this superfamily are distinguished by the possession of lobes indicating the presence of well-developed pilifers and by their distinctly clubbed antennae. The genus Oeneis is an exception, however, in not having the lobes well developed; but this is probably due to specialization, as it seems very closely allied to the Satyrinae, especially in the length of the prothoracic legs. Many of the Papilionoidea have prominent ridges and tubercles on the surface of the body, but there are also many genera in which the body surface is quite smooth and destitute of tubercles and ridges. The epicranial suture is present in three families, Megathymidae, Hesperiidae, and Lycaenidae. There has been a great deal of discussion and disagreement over the arrangement and subdivision of the families of the Papilionoidea. Some have divided it into two superfamilies, Hesperioidea and Papilionoidea, but the pupae show no characters to warrant such a division. The family Lycaenidae has been considered by many as the most specialized, or among the most specialized, of the families, yet it still retains the epicranial suture. In this family, however, the labial palpi are entirely concealed except in the case of the aberrant genus Feniseca, and the shortening of the prothoracic legs is similar to the condition found in the Nymphalidae. It is impossible without further study of existing forms and a larger series of species to discuss fully the relationships between the different families. It is sufficient for the present to state that the Lycaenidae seem more nearly related to the generalized Hesperiidae, but have developed in a similar manner to the Nymphalidae, and that the Pieridae, Papilionidae, and Nymphalidae seem very closely related. The families of Papilionoidea may be separated as follows:

a. Proximo-lateral angles of the maxillae extending laterad to the eyepieces.
  b. Maxillae never reaching the caudal margin of the wings; wings adjacent on the meson caudad of the maxillae. . MEGATHYMIDAE.

bb. Maxillae always extending to the caudal margin of the wings and sometimes beyond; wings never adjacent on the meson.
HESPERIIDAE.

aa. Proximo-lateral angles of the maxillae never extending laterad to the eye-pieces.

b. Mesothoracic legs never extending cephalad to the eye-pieces.

c. Epicranial suture always present; head without projections; exposed part of maxillae never as long as the wings.
LYCAENIDAE.

cc. Epicranial suture never present; head always with prominent projections; exposed part of maxillae usually as long as the wings.

d. Head with two prominent projections, one at each cephalo-lateral angle; metathoracic wings visible in ventral view.
PAPILIONIDAE.

dd. Head with a median projection; metathoracic wings not visible in ventral view.....PIERIDAE.

bb. Mesothoracic legs extending cephalad to the eye-pieces and for a short distance between the sculptured eye-piece and the antenna.
NYMPHALIDAE.

Family MEGATHYMIDAE

The Megathymidae, or giant skippers, are evidently the most generalized of the Papilionoidea although they differ but little from the more generalized Hesperiidae, some doubt existing as to whether they show enough difference to warrant their being considered as a distinct family. However, as only one pupa of this family has been seen by the writer and as that had lost some of the face-parts so that a complete description can not be given, no very definite stand can be taken here as to its position in the superfamily. The members of the superfamily Papilionoidea, as a general rule, possess but little freedom of motion in the free segments and these are rarely capable of being telescoped. In the Megathymidae not only are the free segments capable of a great deal of motion and of being telescoped, but there appears to be dorsal motion possible between the third and fourth abdominal segments, and the seventh abdominal segment appears to possess freedom of motion in the male. The abdominal segments are of nearly equal length, and the eighth, ninth, and tenth are distinctly segmented. These characters, however, appear to be retained in such generalized Hesperiidae as the genera Calpodes and Amblyscirtes, in which if all the above-mentioned segments do not retain freedom of motion they have certainly but recently lost it. In placing this family in the Papilionoidea it has been assumed that the pupae possess lobes indicating the presence of pilifers, but these parts

were absent in the pupa examined. The labial palpi are represented by a small triangular area, but it is not known whether or not maxillary palpi are retained. The maxillae are much shorter than in the Hesperiidae, being only about two thirds the length of the wings, but this indicates nothing as to their position, as both generalized and specialized pupae possess short maxillae. None of the other appendages are longer than the maxillae except the wings, which lie adjacent on the meson caudad of the maxillae. The epicranial suture is present and the vertex is of equal length throughout, being about one fifth the length of the prothorax measured on the meson. The entire body surface is covered with a whitish bloom, and on the dorsum of abdominal segments 7–10 there is in addition a dense covering of rather coarse setae. The pupa examined was 40 mm. in length and about 10 mm. in breadth, and belonged to the genus Megathymus.

The following species was examined:

Megathymus yuccae Boisduval and Le Conte.

Family Hesperiidae

The Hesperiidae retain considerable freedom of motion of the abdominal segments, and in many genera it would seem that dorsal motion is possible between the third and fourth abdominal segments and that the seventh abdominal segment is free in the male, or at least that they have only recently lost the power of motion. The epicranial suture is present in all genera, and the vertex is about one fifth the length of the prothorax measured on the meson, while the lateral margins are considerably longer. The labrum in most genera is considerably cephalad of its normal position. The antennae never reach to the caudal margin of the wings but are from two thirds to three fourths of their length. The prothoracic legs are about half the length of the wings, the mesothoracic usually two thirds of the same, while the metathoracic pair is seldom visible. The maxillae always extend to the caudal margins of the wings and frequently considerably beyond. The mesothoracic spiracles usually have a peculiar kind of plug or plate which seems to form an external closing apparatus or guard, while some have prominent tubercles caudad of the opening, usually with a dense covering of setae. The thorax and abdomen usually have a more or less dense covering of setae, and some of the species have the entire body covered with a whitish bloom, which is of comparatively rare occurrence among lepidopterous pupae. The abdomen frequently has a furrow on the dorsum between the ninth and tenth segments, similar to the furrows found in the Pyralididae but never so deep. The cremaster in all genera is more or less trian-

gular, with hooked setae on the distal end, and frequently has an impressed triangular area on the dorsum. The classification of the Hesperiidae has long been in dispute, and with the limited amount of material available for examination it is impossible to state just how a classification of the pupae would agree with any of the proposed schemes. It is believed, however, that Scudder's arrangement would probably be followed, as the material available falls readily into his groups. As to the relationship between these groups there might be some difference of opinion. The pupae at first sight are readily divided into two groups, one with the abdominal segments caudad of the fourth considerably shortened, possessing narrow flanged plates on the movable segments which prevent the telescoping of the body, and with the segmentation indistinct between the fixed caudal segments (Fig. 77). This group also has the body prominently convex on the dorsum of the mesothorax and on the entire ventral surface of the thorax and abdomen. The labrum is cephalic in position. The other group possesses abdominal segments of more nearly equal length, having distinct sutures between the fixed caudal segments and the movable segments capable of being telescoped. This group has apparently just recently lost the power of motion in the seventh abdominal segment of the male and dorsal motion between the third and fourth abdominal segments. The body is shaped like the majority of lepidopterous pupae, and the labrum never quite reaches the cephalic margin of the body. Of this group, the genera possessing maxillae extending beyond the caudal margin of the wings, Calpodes (Fig. 78) and Amblyscirtes, are undoubtedly more generalized, not on account of the maxillae, but because in all the other members of the group there is considerably more consolidation of the caudal abdominal segments, so that they seem intermediate in position between the genera mentioned above and the first group. The following table will serve to separate the genera of Hesperiidae:

a. Abdominal segments 5–7 never with an elevated ridge or flanged plate along the cephalic margin and always capable of being telescoped; body never with a prominent convexity on the ventral surface in the region of abdominal segments 1–4.
  b. Maxillae extending free for a considerable distance beyond the caudal margin of the wings.
    c. Maxillae extending beyond the caudal margin of the body; head with a long cephalic projection..... *Calpodes* Hübner.
    cc. Maxillae never extending beyond the caudal margin of the body; head never with a long cephalic projection.
      Amblyscirtes Scudder.

bb. Maxillae never extending free beyond the caudal margin of the wings.

c. Body with a dense covering of long setae and whitish bloom; mesothoracic spiracle with a strongly elevated oval area adjacent to its caudal margin, this area chitinized in the center and surrounded by a dense band of short setae with a longitudinally striate chitinized rim forming an outer margin.
Pholisora Scudder.

cc. Body sparsely covered with short inconspicuous setae; dense whitish bloom never present; mesothoracic spiracle with a somewhat circular elevation adjacent to its caudal margin, which is entirely covered with setae.....*Thanaos* Boisduval.

aa. Abdominal segments 5–7 with an elevated ridge or flanged plate along the cephalic margin which prevents their being telescoped; body with a prominent convexity on the ventral surface in the region of abdominal segments 1–4.

b. Mandibular area with distinct tubercles which are usually black and bearing stout setae; head slightly narrower than the mesothorax.

c. Mesothoracic spiracle semicircular in outline, the opening circular, a broad thick band of setae around the caudal half.

d. Dorsal furrow or depression on the ninth abdominal segment with its caudal margin distinctly crenulate; ventral surface of cremaster with an elongate furrow broadened out at the distal end of the cremaster.....*Thorybes* Scudder.

dd. Dorsal furrow or depression on the ninth abdominal segment not distinctly crenulate; ventral surface of cremaster with a triangular depression broad at the proximal end and narrowed to the distal end of the cremaster.
Epargyreus Hübner.

cc. Mesothoracic spiracle semicircular in outline, the opening circular and surrounded by a broad thick band of setae, and caudad of this a distinctly elevated chitinized ridge forming an outer margin.....*Cocceius* Godman and Salvin.

bb. Mandibular area smooth, without tubercles; head as broad as the mesothorax .....*Eudamus* Swainson.

The following species were examined:
Calpodes ethlius Cramer
Amblyscirtes vialis Edwards
Pholisora catullus Fabricius
Thanaos brizo Boisduval and Le Conte, *lucilius* Lintner
Thorybes daunus Cramer
Epargyreus tityrus Fabricius
Cocceius pylades Scudder
Eudamus proteus Linnaeus

Family Lycaenidae

The Lycaenidae are small pupae, between 8 and 15 mm. in length, which have the general shape of arctians although they are generally less curved on the ventral surface (Fig. 79). They retain a small portion of the vertex on each side and the epicranial suture usually touches the caudal margin of the head at the meson, making each half of the vertex triangular. The lobes indicating the presence of pilifers always meet on the meson except in the genus Feniseca. The antennae always extend to the caudal margin of the wings and lie adjacent on the meson, concealing the distal ends of the maxillae. The prothoracic legs are shorter than usual, varying from two fifths to one third the length of the wings. The mesothoracic legs are about half the length of the wings and the metathoracic pair are never visible. The body is usually quite free from projections or elevations, Feniseca being the only exception known, and it bears small rounded tubercles on its dorsal surface. The head is limited to the ventral surface of the body, and the suture between it and the prothorax is located on the cephalic margin of the body, sometimes forming a slight ridge. The prothorax is longer than is usual in Papilionoidea, being about half as long as the mesothorax. There is little, if any, motion possible between any of the abdominal segments, and they fit together so as to form a smooth surface. Even the pupal skin after dehiscence shows no separation of the abdominal segments. The surface of the thorax and abdomen is covered with a reticulation of fine elevated lines with small papillae at their intersections and usually in the spaces between. These papillae usually bear cuticular appendages, of various types, the most peculiar being the fungiform type of the genera Chrysophanus and Heodes. There is no cremaster present in any member of the family. The ventral surface of the abdomen frequently bears groups of small hooked setae. The genital openings are usually obscured. The anal opening is peculiar, in many forms being transverse instead of longitudinal. The mesothoracic spiracles are closed by a plug or plate which fills up the opening and usually presents a honeycombed appearance. The following table will serve to separate the genera of Lycaenidae:

a. Exposed portion of maxillae never more than three fifths the length of the wings; cuticular appendages of the body never fungiform.

b. Ventral surface of the body never with hooked setae caudad of the anal opening; thorax and abdomen usually densely covered with spiculate cuticular appendages; exposed portion of maxillae scarcely more than half the length of the wings.

c. Ventral surface of ninth abdominal segment with a group of hooked setae on each side of the meson.
d. Thorax with the median line slightly elevated; raised lines of the reticulations very prominent; papillae short, cylindrical. ..... *Incisalia* Minot.
dd. Thorax with the median line never elevated; raised lines of reticulations not prominent; papillae conical. *Uranotes* Scudder.
cc. Ventral surface of ninth abdominal segment never with hooked setae on each side of the meson.
d. Ventral surface of ninth abdominal segment with a group of straight cuticular appendages on each side of the meson; setae on body very dense and about one fourth the length of the abdominal segments; papillae conical. *Mitura* Scudder.
dd. Ventral surface of ninth abdominal segment without cuticular appendages of any kind; setae of body not dense, but long, usually half the length of the segment; papillae short, cylindrical..... *Thecla* Fabricius.
bb. Ventral surface of body with hooked setae caudad of the anal opening; papillae most numerous in the spiracular region; thorax and abdomen sparsely covered with short cuticular appendages with very minute spicules; exposed portion of maxillae three fifths the length of the wings.
c. Papillae of the spiracular region confined to an area caudad of the spiracle; spiracle of the second abdominal segment not adjacent to the wing..... *Cyaniris* Dalman.
cc. Papillae of the spiracular region surrounding the spiracle; spiracle of the second abdominal segment adjacent to the wing, the distance between them less than the width of the spiracle ..... *Rusticus* Hübner.
aa. Exposed portion of the maxillae more than three fifths the length of the wings.
b. Body of typical lycaenid shape, never flattened at the caudal end; cuticular appendages fungiform.
c. Fungiform cuticular appendages small and inconspicuous, not visible with a low-power lens; color light yellowish brown, not spotted..... *Chrysophanus* Hübner.
cc. Fungiform cuticular appendages large and conspicuous, easily visible with a low-power lens; color dark brown with black spots ..... *Heodes* Dalman.
bb. Body with the caudal end flattened and curved slightly ventrad. *Feniseca* Grote.

The following species were examined:

Incisalia niphon Hübner

Uranotes melinus Hübner

Mitura damon Cramer
Thecla acadica Edwards, *calanus* Hübner, *liparops* Boisduval and Le Conte
Cyaniris ladon Cramer
Rusticus scudderi Edwards
Chrysophanus thoe Boisduval
Heodes hypophleas Boisduval
Feniseca tarquinius Fabricius

Family Papilionidae

The pupae of this family are usually long and slender, tapering gradually to the pointed caudal end, which is called the cremaster although it seldom resembles a true cremaster, and extends very little beyond the anal opening. The body always has two prominent cephalic projections, one at each cephalo-lateral angle of the head, a less prominent lateral projection on each side the metathorax at the base of each wing, and a low median carinate ridge which extends along the prothorax on to the mesothorax for about half its length, where it forms a more or less prominent projection. From this prominence the ridge divides, the remainder of its course being on the metathorax, the divisions sometimes extending to the abdomen to form the dorso-lateral abdominal ridges. There is also usually present a lateral ridge on each side. These four ridges are continued to the end of the body, and are often present on the tenth segment or on the cremaster when absent from the remainder of the abdomen. On the ventral surface there is usually a ridge on each side of the face-parts, beginning at the cephalic projections and extending to the proximo-lateral angles of the maxillae.

The labrum is in its normal position and the lobes which indicate the presence of pilifers seldom meet on the meson, but are separated by a small portion of the labial palpi. The epicranial suture is never present, and the proximal ends of the antennae approach each other very closely on the dorsal surface of the head. The antennae never extend as far caudad as the wings. The wings are usually somewhat pointed on the ventral surface near the meson and the metathoracic wing is always visible here, extending for a considerable distance caudad of the mesothoracic wings. The maxillae always extend to the caudal margin of the wings. The legs are of the length usual in lepidopterous pupae with the exception of the genus Iphiclides, in which the prothoracic legs only are about the usual length, the mesothoracic legs ending before the former—a very rare occurrence in this order. The genital openings are located in the usual positions, those of the

female being confluent on the ventro-meson of the eighth and ninth abdominal segments. Just caudad of the genital openings, at the cephalic margin of the tenth abdominal segment is a small tubercle on each side of the meson closely appressed to the surface of the body. The caudal end of the body bears a mass of very short hooked setae. The fourth, fifth, and sixth segments are movable, although they fit closely together to form an even surface and are not capable of telescoping. At dehiscence they separate, showing deep incisions. The genera of Papilionidae may be separated as follows:

a. Body surface without distinctly carinate ridges; dorsal surface of abdomen always with a row of small rounded tubercles on each side of the meson, the largest on segments 4–7, and usually a row of smaller tubercles on each side of the spiracles; ventral surface with two distinct tubercles on each leg, a transverse row near the caudal margin of the mesothoracic wings, and often on the veins near the margin ..... *Papilio* Linnaeus.

aa. Body surface with distinctly carinate ridges, but never with small rounded tubercles on the abdomen, occasionally with very minute tubercles on the wings and other appendages.

b. Body without prominent lateral expansions of the abdominal segments or dorsal carinate ridges.

c. Body with a very low dorso-mesal ridge on the thorax with a small mesothoracic elevation; a prominent carinate ridge at each lateral margin of the body and no dorso-lateral ridge; cephalic projections large and prominent; body very strongly convex on the ventral surface in the region of the wings. *Euphoeades* Hübner.

cc. Body with a low dorso-mesal ridge on the thorax ending in a very prominent mesothoracic elevation; a very low dorso-lateral and lateral ridge on each side of the abdomen; cephalic projections not very large; body never strongly convex on the ventral surface..... *Iphiclides* Hübner

bb. Body with prominent lateral expansions of the first four abdominal segments, making this the widest part of the body; abdominal segments with dorsal carinate ridges on each side of the meson, most prominent on segments 5–7, which are highest in the middle of each segment and curve to each margin, giving it a scalloped appearance in lateral view..... *Laertias* Hübner.

The following species were examined:

Laertias philenor Linnaeus

Iphiclides ajax Linnaeus

Euphoeades troilus Linnaeus, *palamedes* Drury

Papilio daunus Boisduval, *eurymedon* Boisduval, *rutulus* Boisduval, *glaucus* Linnaeus, *polyxenes* Fabricius, *thoas* Linnaeus, *machaon* Linnaeus, *zolicaon* Boisduval, *brevicauda* Saunders

Family Pieridae

The pupae of this family resemble the Papilionidae very strongly as to the general shape of the body and arrangement of ridges and projections. They are much smaller, however, and are easily recognized by the fact that they possess a single median cephalic projection instead of two cephalo-lateral projections as do the Papilionidae. The epicranial suture is never present. The labrum is usually slightly cephalad of its normal position and a small portion of the labial palpi is always exposed. The maxillae vary in length from two thirds the length of the wings to extending slightly beyond their caudal margin. The legs are of normal length. The antennae are more distinctly clubbed than in the Papilionidae and sometimes reach the caudal margin of the wings. The caudal end of the body is very like that of the Papilionidae except that the four ridges are seldom present, and the hooked setae are inserted in a slight concavity. The genital openings are in the usual positions. On the ventral surface of the tenth abdominal segment there is a low ridge, circular in outline, which encloses the anal opening and terminates at its cephalic end in a small tubercle on each side of the meson. These tubercles are located just caudad of the genital openings. Similar tubercles and ridges are found in the Nymphalidae, but they are rather more prominent in that family. Tubercles without the ridges occur in the Papilionidae.

There is very little question as to whether or not the Pieridae and Papilionidae are related, but which is the more specialized seems to be a questionable point with all workers in the group. Aside from the question of prominences or projections, which, after all, seems a matter of small importance, there is little of fundamental difference between the two families excepting the length of the thoracic segments, which are more generalized in the Papilionidae, and the ridges and tubercles just mentioned on the ventral surface of the Pieridae, which resemble the Nymphalidae. The Nymphalidae certainly seem to be the most specialized of the Papilionoidea, although this is another much debated question. The two families have undoubtedly been developed from a common ancestor and represent parallel lines of development. The genera of Pieridae may be separated by the following table:

a. Distance from the cephalic margin of the prothorax to the distal end of the cephalic projection much less than the length of the prothorax; ventral line of body often convex but never forming a prominent angle.

b. Thorax with a strongly carinate median ridge, highest at the middle of the mesothorax, and forming a prominent projection; ab-

domen with a lateral carinate ridge on each side, forming two prominent projections on the second and third segments, the latter more prominent; a median carinate ridge from the fourth abdominal segment to the caudal end of the body; ventral line of body practically straight.....*Pontia* Fabricius.

bb. Thorax without a strongly carinate median ridge, either without a median ridge or with one of equal height throughout.

c. Ventral surface of body convex, but without any prominent rounded projection; a low lateral ridge present along the wings, extending on the abdomen to the caudal end of the body. *Eurymus* Swainson.

cc. Ventral surface of body produced into a prominent rounded projection which, near the caudal margin of the wings, is as wide as the body just caudad of the wings; body without any prominent ridges, a lateral ridge present along the wings but scarcely indicated on any of the abdominal segments except the tenth .....*Eurema* Hübner.

aa. Distance from the cephalic margin of the prothorax to the distal end of the cephalic projection about equal in length to the thorax; ventral line of body forming a prominent obtuse angle at a point about equidistant from the cephalic and caudal ends..*Synchloe* Hübner.

The following species were examined:
Pontia protodice Boisduval and Le Conte, *rapae* Linnaeus
Eurymus philodice Godart
Eurema nicippe Cramer
Synchloe genutia Fabricius

Family Nymphalidae

The members of this family have been variously subdivided. Some writers make several families of the species included here, while others divide them into subfamilies and tribes. At present no good characters are known for the division of this group into families, but it must be admitted that the same difficulties lie in the way of dividing it into the subfamilies and tribes proposed by Scudder; consequently, several subfamily names have been introduced here to facilitate the grouping of the species. The Nymphalidae are distinguished from all other families lacking the epicranial suture by the fact that both prothoracic and mesothoracic legs extend cephalad to the eye-pieces and the mesothoracic legs extend for a short distance between the sculptured eye-pieces and the antennae. The prothoracic legs are very short, rarely more than one third the length of the wings. The antennae and maxillae, except in a few instances, reach to the caudal margin of the

wings. The proximal ends of the antennae extend almost to the meson on the dorsum of the head. The labial palpi are represented by a very small portion caudad of the labrum and in many cases are entirely concealed. With the exception of *Anaea andria* the metathoracic wings are not visible on the ventral surface. The genital openings are in the usual position. The circular furrow enclosing the anal opening with the small tubercles caudad of the genital openings, is present in nearly all genera. When tubercles are present on the surface of the body they are usually on the dorsum of the abdomen and are arranged in seven rows, as follows: a dorso-mesal row (Fig. 81, dmt), a dorso-lateral row on each side about half-way between the meson and the spiracles (Fig. 81, dlt), and a dorsal (Fig. 81, dst), and ventral row (Fig. 81, vst) on each side of the abdominal spiracles. The subfamilies of Nymphalidae may be separated as follows:

a. With prominent tubercles on the dorsal surface of the body, or at least on the abdomen, a dorso-mesal row, a dorso-lateral row on each side, and a row dorsad and ventrad of each row of spiracles. NYMPHALINAE.

aa. Without prominent tubercles on the dorsal surface, at least not arranged in rows as above.

b. Second abdominal segment with a prominent carinate median elevation, somewhat constricted at its base..... BASILARCHINAE.

bb. Second abdominal segment without a prominent, carinate median elevation.

c. Body compressed, with a distinct dorso-mesal carina on the thorax and abdomen; ventral surface of ninth and tenth abdominal segments with hooked setae, the tubercles on the ninth segment covered with very short hooked setae.... APATURINAE.

cc. Body not compressed; dorso-mesal carina never present on both thorax and abdomen.

d. Abdominal segments caudad of the wings rapidly tapering and forming a sort of hemisphere; dorsum of abdomen with a prominent transverse ridge.

e. Head with a prominent transverse ridge, extending along the middle of the eye-pieces and the lateral margin of the body; second, third, and fourth abdominal segments of approximately the same length; cremaster directed ventrad; transverse ridge on the fourth abdominal segment. ANAEINAE.

ee. Head without a transverse ridge, but with two prominent tubercles; second abdominal segment longer than any of the others; cremaster directed caudad; transverse ridge on the third abdominal segment tuberculate for its entire length ..... EUPLOEINAE.

dd. Abdominal segments caudad of the wings not rapidly tapering to form a hemisphere; dorsum of abdomen never with a transverse ridge.
e. Mesothorax prominently elevated; head with a transverse ridge forming slightly produced cephalo-lateral angles; cremaster with hooked setae.....SATYRINAE.
ee. Mesothorax not prominently elevated; head never with a tranverse ridge; caudal end of body without hooked setae; cremaster never present .....OENEINAE.

Subfamily *Nymphalinae*

This subfamily includes all the genera with prominent tubercles on the surface of the body. There are usually seven rows of these, mostly on the dorsal surface of the abdomen, as follows: a dorso-mesal row; on each side of this a dorso-lateral row; and a row dorsad and ventrad of the abdominal spiracles on each side (Fig. 81). The majority of species have a cephalo-lateral projection on each side of the head; in some these are very prominent; in others, reduced to small rounded tubercles or wanting. The body is usually strongly convex near the caudal margin of the wings on the ventral surface, and the cremaster is curved ventrad. The cremaster is more prominent in this subfamily than in the family Papilionidae and bears a mass of short hooked setae at its distal end. The species of Nymphalinae have been grouped into three tribes, mostly according to the size and arrangement of the tubercles. These three tribes may be separated as follows:

a. Dorso-mesal tubercles smaller than those of the dorso-lateral rows; cremaster never with prominent lateral projections at the base.
b. Cremaster longer than broad; dorso-mesal tubercles always present on abdominal segments 3–8 and usually on the second segment .....VANESSINI.
bb. Cremaster usually broader than long; dorso-mesal tubercles often wanting and never present cephalad of the fourth segment. ARGYNNINI.
aa. Dorso-mesal tubercles equal in size to those of the dorso-lateral rows; cremaster always with a lateral projection on each side at the base. MELITAEINI.

TRIBE VANESSINI

This tribe includes the species with all the rows of tubercles represented and most of them complete. The tubercles of the dorso-mesal row are considerably smaller than those of the dorso-lateral row, which are usually very prominent. The rows of tubercles on either

side of the spiracles are always very small. The cremaster is long and never has prominent lateral tubercles at its proximal end. The genera of Vanessini may be separated by the following table:

a. Cephalic prominences conical, with length and breadth approximately equal; dorso-lateral tubercles on the fourth abdominal segment always larger than the others.
  b. Dorso-lateral tubercles on abdominal segments 2–7 long and sharp, spine-like, the length considerably greater than the breadth; dorso-mesal tubercle absent on the second abdominal segment. *Euvanessa* Scudder.
  bb. Dorso-lateral tubercles on abdominal segments 2–7 not sharp and spine-like; the length scarcely, if any, greater than the breadth; dorso-mesal tubercle present on the second abdominal segment.
    c. Dorso-lateral tubercles on fourth abdominal segment at least twice the size of the others; median elevation of the mesothorax a compressed carinate ridge and usually very prominent. *Polygonia* Hübner.
    cc. Dorso-lateral tubercles on fourth abdominal segment very little larger than the others; median elevation of the mesothorax pyramidal and not very prominent..... *Aglais* Dalman.

aa. Cephalic prominences usually blunt, the length less than the breadth; dorso-lateral tubercles on the fourth abdominal segment never larger than the others.
  b. Cephalic prominences broadly rounded; scarcely elevated beyond the outline of the body; no distinct prominence on the median line of the mesothorax..... *Junonia* Hübner.
  bb. Cephalic prominences distinctly elevated beyond the outline of the body; a distinct prominence on the median line of the mesothorax ..... *Vanessa* Fabricius.

The following species were examined:

Euvanessa antiopa Linnaeus

Polygonia interrogationis Fabricius, *comma* Harris, *faunus* Edwards, *progne* Cramer

Aglais milberti Godart

Junonia coenia Hübner

Vanessa atalanta Linnaeus, *huntera* Fabricius, *cardui* Linnaeus

Tribe ARGYNNINI

The species included here resemble those of the preceding tribe, excepting that the dorso-mesal row of tubercles is only present on a few segments or is entirely wanting. The cremaster is short and broad and never has a prominent projection on each side at the proximal end. The genera of Argynnini may be separated by the following table:

a. Dorso-lateral row of tubercles of approximately equal size.
   b. Dorso-mesal row of tubercles present on abdominal segments 4–7; dorso-lateral tubercles much larger than the stigmatal rows; carinate ridge present on mesothorax.....*Argynnis* Fabricius.
   bb. Dorso-mesal row of tubercles absent on all segments; dorso-lateral tubercles about equal in size to the dorsal stigmatal row; mesothorax without a carinate ridge.....*Euptoieta* Doubleday.

aa. Dorso-lateral row of tubercles of different sizes, the largest on the third abdominal segment.
   b. Body with a very strong ventral curve opposite the third and fourth abdominal segments; mesothorax with a strongly elevated median ridge throughout its length; head projections very prominent, irregularly bilobed.
   Agraulis Boisduval and Le Conte.
   bb. Body without a strong ventral curve; mesothorax with a small ridge on the caudal half; head projections short, pointed.
   Brenthis Hübner.

The following species were examined:
Argynnis cybele Fabricius
Euptoieta claudia Cramer
Agraulis vanillae Linnaeus
Brenthis myrina Cramer

TRIBE MELITAEINI

The species in this group have the dorso-mesal and dorso-lateral tubercles of approximately equal size, but none of them are very large and they are usually rounded. The cremaster always has a prominent projection on each side at its proximal end. The genera of Melitaeini may be separated as follows:

a. Tubercles of the dorsal spiracular row not present on the second abdominal segment; no tubercles present on the eighth abdominal segment.
   b. Dorsum of abdomen with a distinct tranverse ridge on the fourth segment; dorsal spiracular row of tubercles not distinct on any of the segments .....*Phyciodes* Hübner.
   bb. Dorsum of abdomen without a transverse ridge on the fourth segment; dorsal spiracular row of tubercles very large on the third and fourth abdominal segments .....*Charidryas* Scudder.

aa. Tubercles of the dorsal spiracular row present on the second abdominal segment; tubercles present on the eighth abdominal segment.
   b. Tubercles of the eighth abdominal segment nearly as large as the others, the abdominal tubercles all broadly rounded and never longer than broad; cremaster with a deep depression on the dorsal surface and a circular depression on the ventral surface, the lateral tubercles very prominent, rounded, smooth and polished.
   Euphydryas Scudder.

bb. Tubercles of the eighth abdominal segment much smaller than the others, the abdominal tubercles all somewhat pointed and longer than broad; cremaster never with a deep depression on the dorsal surface, but with a long narrow furrow on the ventral surface, the lateral tubercles somewhat triangular in outline and slightly rugose like the cremaster.....*Cinclidia* Hübner.

The following species were examined:
Phyciodes tharos Drury
Charidryas nycteis Doubleday and Hewitson
Euphydryas phaeton Drury
Cinclidia harrisii Scudder

Subfamily *Basilarchinae*

The genus Basilarchia differs from all the genera of Nymphalinae, with which it is generally included, on account of the absence of the rows of tubercles. There are two cephalic projections, as in many Nymphalinae, and on the dorsum of the second abdominal segment there is a very large carinate projection. This is somewhat oval in outline as seen in lateral view, being constricted at the base. The body is not prominently excurved in the region of the appendages as in the Nymphalinae, but is of the same general shape. It agrees with the Nymphalinae only in the characters common to all members of the subfamily and is therefore placed in a separate subfamily.

The following species were examined:
Basilarchia astyanax Fabricius, *arthemis* Drury, *archippus* Cramer.

Subfamily *Apaturinae*

The species of this subfamily, included by Scudder in the Nymphalinae, show no characters which unite them with that subfamily. The group, according to Scudder, included the genera Chlorippe and Anaea, which differ so widely in the pupae that they could not well be combined in the same subfamily. The name Apaturinae has been retained for the genus Chlorippe. These pupae are strongly compressed, with a prominent median dorsal carinate ridge. There are two cephalic projections and the ventral surface of the body forms a straight line while the dorsum is strongly arched. The antennae are slightly elevated and tuberculate. The genital openings are sunken and almost concealed. On either side of the anal opening near its cephalic end there is a small tubercle covered with hooked setae. The cremaster is short and triangular, and the hooked setae are nearly all on the ventral surface.

The following species were examined:
Chlorippe celtis Boisduval and Le Conte, *clyton* Boisduval and Le Conte.

Subfamily *Anaeinae*

This subfamily includes a single genus, Anaea, which was included with Chlorippe in the tribe Apaturini by Scudder. The pupae are so different, however, that they have in common only the ordinary nymphalid characters. The body is never compressed, but the abdominal segments caudad of the wings taper very rapidly and form a hemisphere. The long cremaster is inserted near the center of the hemisphere and curves ventrad. The fourth segment has a prominent transverse ridge. The ventral surface of the abdominal segments caudad of the wings is very short and the genital openings are concealed. The head has a prominent transverse ridge at the cephalic end which extends caudad through the middle of the eye-pieces and along the lateral margin of the body. The metathorax has a rather prominent rounded ridge on the meson. The antennae and maxillae extend to the caudal margin of the wings.

The following species was examined:
Anaea andria Scudder.

Subfamily *Euploeinae*

This subfamily is equivalent to the family Lymnadidae of some authors. It includes two genera, of which only Anosia has been examined. The general shape of the body is very like that of the genus Anaea of the subfamily Anaeinae, but it has the second abdominal segment very long, as well as the thorax, and the cremaster extends caudad. There is never a ridge on the head, but it has a tubercle at each cephalo-lateral margin. The transverse ridge is on the third segment and is tuberculate. The maxillae do not reach the caudal margin of the wings in Anosia and the antennae lie adjacent on the meson caudad of them.

The following species was examined:
Anosia plexippus Linnaeus.

Subfamily *Satyrinae*

The Satyrinae are similar in shape to the Nymphalinae, but have no tubercles on the surface of the body and but few prominent ridges. The head always has a prominent transverse ridge at the cephalic end, and this often forms slight cephalo-lateral angles. There is also a slightly carinate ridge at each lateral margin of the body extending

as far caudad as the second abdominal segment. The metathorax always has a median elevation, which sometimes forms a prominent angle. The circular ridge surrounding the anal opening is not strongly elevated but the tubercles are prominent on each side of the genital opening on the ninth segment. The genera of this subfamily may be separated by the following table:

a. Cremaster broader than long, with hooked setae present on the ventral surface; genital opening never with a tubercle on each side. *Cissia* Doubleday.

aa. Cremaster longer than broad, the hooks always inserted at the distal end, never on the ventral surface; genital opening always with a distinct tubercle on each side.

b. Mesothoracic elevation rounded; cremaster concave at tip with the hooked setae inserted in the hollow; body surface with fine indeterminate striations ..... *Cercyonis* Speyer.

bb. Mesothoracic elevation with a distinct angle; cremaster not concave at tip; body surface smooth..... *Satyrodes* Scudder.

The following species were examined:
Cissia eurytus Fabricius
Cercyonis alope Fabricius
Satyrodes canthus Linnaeus

Subfamily *Oeneinae*

The genus Oeneis has none of the distinguishing characters of the subfamily Satyrinae and therefore is not here included with the members of that group. The body has the general shape of a lycaenid, and the segments seem as devoid of motion (Fig. 80). In other respects it is a typical nymphalid. The antennae do not quite reach the caudal margin of the wings, and overlie the maxillae at their distal end, so that the antennae are adjacent on the meson. Their proximal ends are very near the meson on the dorsal surface of the head. There is no distinct ridge surrounding the anal opening, nor are any tubercles present caudad of the genital openings. There is no cremaster, nor hooked setae at the caudal end of the body.

Only one species was examined:
Oeneis semidea Say.

Specialized pupae without pilifers

This division includes the remaining superfamilies of Lepidoptera. The seventh abdominal segment is fixed in both sexes in all the families except the Epermeniidae, in which this segment is fixed in the

male. None of the species included here have dorsal movement between any of the segments cephalad of the fourth. In this they differ from the superfamilies Pyralidoidea and Papilionoidea, some members of which retain dorsal movement of the third abdominal segment. This group includes all the most specialized families. The origin of most of these is doubtful. The Noctuoidea show the strongest relationship to the Pyralidoidea; the Notodontoidea, to the Gelechioidea. All the evidence at present points to the fact that the Pyralidoidea and Gelechioidea have descended from a common ancestor closely allied to the Yponomeutoidea. The Sphingoidea and Saturnioidea, which show considerable relationship to each other, seem to have arisen from a common stem with the more generalized Bombycoidea, which in turn seem nearly related to the Noctuoidea and Notodontoidea.

Superfamily YPONOMEUTOIDEA

The families included here show well-developed labial palpi, and have a large portion of the prothoracic femora exposed. All show the maxillary palpi except the Coleophoridae, and the same arrangement of parts prevails throughout the superfamily. The epicranial suture is present in all families. The prothorax is always very short on the meson, but much longer on each lateral margin so that each half is triangular. The appendages always reach beyond the caudal margin of the fourth segment, and in some cases are almost as long as the body. They are soldered firmly to each other but are free from the body wall. Abdominal segments 1–4 are longer than any of the others. There are usually spines or setae present at the caudal end of the body but seldom a cremaster. The pupae are usually less than 10 mm. in length. The families may be separated by the following table:

a. Cremaster present, but short, with hooked setae at the distal end; ninth abdominal segment with a deep lateral cavity on each side; seventh abdominal segment free in the male.....Epermeniidae.
aa. Cremaster absent; ninth abdominal segment never with a deep lateral cavity; seventh abdominal segment fixed in both sexes.
  b. Maxillary palpi present; caudal end of body without lateral prolongations ending in spines.....Yponomeutidae.
  bb. Maxillary palpi never present; caudal end of body with lateral prolongations ending in sharp spines.....Coleophoridae.

Family Epermeniidae

This family, which has usually been combined with the Elachistidae, or, by some writers, with the Scythridae, is here associated with

the Yponomeutidae, the only important differences between the two families being the freedom of the seventh abdominal segment in the male and the presence of a very short cremaster in the Epermeniidae. Another difference is that in Epermeniidae the wings and other appendages are somewhat elevated at the meson and slope to each lateral margin. A comparison of Figure 68 with Figures 82, 83, and 85 will show the similarity in arrangement of parts in the Yponomeutidae and Epermeniidae.

The following species was examined:
Epermenia pimpinella Murtfeldt.

Family YPONOMEUTIDAE

The genera comprising this family resemble each other very strongly in all important characteristics, but nevertheless possess very clear generic distinctions. They closely resemble certain of the generalized gelechiids (Figs. 88, 89), and many authors have associated those genera with the yponomeutids. The presence of a distinct fronto-clypeal suture and the peculiar arrangement of the antennae in the family Gelechiidae, together with the apparent loss of the labial palpi, seem to separate it very clearly from the Yponomeutidae, in which the fronto-clypeal suture is never distinct and the antennae are never adjacent on the meson except in Zelleria (Fig. 82). The typical arrangement of parts is seen in Figures 82, 83, 84, 85, 86, making further description unnecessary. The abdominal spiracles are all considerably produced and tubular, being longest in Plutella. There is no cremaster present in any of the genera. The genera of Yponomeutidae may be separated by the following table:

a. Mesothoracic spiracles produced, tube-like; setae at caudal end of tenth segment hooked; maxillae more than three fourths the length of the wings ..... *Plutella* Schrank.

aa. Mesothoracic spiracles not produced, slit-like; setae at caudal end of tenth segment straight, or occasionally slightly curved at end; maxillae much less than three fourths the length of the wings.

b. Caudal end of tenth segment showing four straight setae, generally two directed laterad and two caudad; maxillary palpi touched by both prothoracic and mesothoracic legs.

c. Maxillary palpi long, reaching the proximo-lateral angles of the maxillae; labial palpi never becoming wider than at their proximal margin; antennae never touching on the meson. *Yponomeuta* Latreille.

cc. Maxillary palpi short, never reaching the proximo-lateral angles of the maxillae; labial palpi wider through most of their length than at the proximal margin; antennae touching on the meson. *Zelleria* Stainton.

bb. Caudal end of tenth segment showing eight setae; four of these on the ventral surface extending laterad and sometimes slightly curved at the tip; mesothoracic legs never reaching cephalad to the maxillary palpi .....*Argyresthia* Hübner.

The following species were examined:
Plutella maculipennis Curtis
Yponomeuta padellus Linnaeus, *malinellus* Zeller
Zelleria celastrusella Kearfott
Argyresthia freyella Walsingham

Family Coleophoridae

This family has usually been associated with the Elachistidae, but since the division of that family the name means very little unless we use it to include the genus Elachista and others closely related, which certainly would not include the Coleophoridae. They seem, rather to be more closely allied to the Yponomeutidae and are so considered here. They differ mainly in the loss of the maxillary palpi and in the lateral extensions of the ninth abdominal segment (Fig. 87). The appendages are usually very long, extending nearly to the caudal margin of the body, and often beyond it, when the movable segments are contracted. The abdominal segments from the first to the sixth are very much longer than the remaining segments.

The following species were examined:
Coleophora caryaefoliella Clemens, *vernoniaeella* Chambers, *malivorella* Riley.

Superfamily GELECHIOIDEA

This superfamily includes those pupae which possess a distinct epicranial suture, with the caudal portions of the antennae lying adjacent on the meson and usually separating at their distal ends to expose the metathoraic legs. The maxillary palpi are usually present, but labial palpi and prothoracic femora are seldom exposed. The body is usually ovate in outline as seen in dorsal or ventral view; widest in the thoracic region and somewhat depressed. The superfamily is closely related to the Yponomeutoidea. It includes here two groups representing two distinct lines of development: the group retaining the fronto-clypeal suture, including the families Lavernidae, Scythridae, Gelechiidae, and Chrysopeleiidae; and those in which it is not distinct or is absent, including the families Oecophoridae, Stenomidae, Cosmopterygidae, and Elachistidae. The latter group may represent a distinct superfamily when all its allied genera have been studied, but at present there is no evidence to warrant such a conclusion. The following table will serve to separate the families of Gelechioidea:

a. Fronto-clypeal suture always distinct for its entire length, sometimes forming a prominent curve or angle at the meson.
  b. Labial palpi exposed for their entire length.
    c. Femora of the prothoracic legs visible; maxillary palpi either reaching the proximo-lateral angles of the maxillae or approaching them very closely; tenth abdominal segment with stout spines at the caudal end.....LAVERNIDAE.
    cc. Femora of the prothoracic legs never visible; maxillary palpi minute; tenth abdominal segment with hooked setae at the caudal end .....SCYTHRIDAE.
  bb. Labial palpi never exposed for their entire length, usually concealed.
    c. Maxillary palpi present and usually reaching the proximo-lateral angles of the maxillae; antennae usually adjacent on the meson for the caudal two fifths of their length, separating at distal ends to show the metathoracic legs.....GELECHIIDAE.
    cc. Maxillary palpi never present; antennae adjacent on the meson for the caudal two fifths of their length but not separated at their distal ends .....CHRYSOPELEIIDAE.
aa. Fronto-clypeal suture never distinct for its entire length and never reaching the meson.
  b. Abdominal segments 4–6 movable, with very deep incisions between the segments on the dorsal and ventral surfaces; body depressed.
    c. Maxillary palpi large, usually reaching the proximo-lateral angles of the maxillae; hooked setae never present on the ventral surface of the ninth abdominal segment.....OECOPHORIDAE.
    cc. Maxillary palpi minute; hooked setae always present on the ventral surface of the ninth abdominal segment.....STENOMIDAE.
  bb. Abdominal segments 4–6 never all movable; incisions between the segments of equal depth on all surfaces; body not depressed.
    c. Maxillary palpi present; sixth abdominal segment movable. COSMOPTERYGIDAE.
    cc. Maxillary palpi absent; no abdominal segments movable. ELACHISTIDAE.

Family LAVERNIDAE

The pupae belonging to this family are more generalized than any other members of the superfamily and closely resemble pupae belonging to the family Yponomeutidae. They have been included here on account of the distinct fronto-clypeal suture, present in all except the more specialized Gelechioidea, and also because the prothorax, which is so short on the meson in Yponomeutidae with each half triangular in outline, in this family loses that condition and becomes almost as long on the meson as at the lateral margins, so that each half is sub-

quadrangular. This is the only family of Gelechioidea which retains both labial palpi and exposed portions of the prothoracic femora. The appendages have the characteristic arrangement of the superfamily (Fig. 88) except that the antennae do not separate near their distal end to expose a portion of the metathoracic legs, but these are seen caudad of the antennae adjacent on the meson. The wings are long and pointed in Lophoptilus, but rounded in Laverna. The first four abdominal segments are longer than the remaining caudal segments in this family, and the appendages are soldered to them, but are free for the remainder of their length. This family has been considered as a subfamily of Elachistidae by most authors, and has usually included Cosmopteryx, which is a much more specialized genus. The following table will serve to separate the genera of Lavernidae:

a. Head long, somewhat pointed, the length more than half the greatest width; fronto-clypeal suture making an acute angle at meson; spines of the tenth segment extending dorsad and not visible in ventral view; exposed part of metathoracic leg about one fifth the length of the portion of the antennae lying adjacent on the meson.
Lophoptilus Sircom.

aa. Head short, blunt, the length about equal to half the greatest width; fronto-clypeal suture making an obtuse angle at meson; spines of tenth segment extending laterad and visible in ventral view; exposed part of metathoracic leg about equal in length to the portion of the antennae lying adjacent on the meson.....*Laverna* Curtis.

Family Scythridae

The pupae of this family also resemble the Yponomeutidae in some respects, and have been included with them by some authors. Others have associated the family with the Elachistidae, while Stainton included it with the Gelechiidae as the genus Butalis. The antennae in this family meet on the meson, but do not separate to show the distal ends of the metathoracic legs as is the general rule in this superfamily. Instead, the mesothoracic wings lie adjacent on the meson caudad of the antennae, and the appendages are firmly soldered to each other and to the body (Fig. 89). As the appendages extend caudad for about half the length of the seventh abdominal segment, it follows that there can be no motion possible between any of the abdominal segments, unless there be slight dorsal motion. The prothorax is typically gelechiid in character. The abdominal spiracles are considerably produced and tubular, their length varying in the different species. The setae of the body are nearly all hooked, and a few longer ones are pres-

ent at the caudal end of the body. Only one genus of this family was available for study.

The following species were examined:
Scythris eboracencis Zeller, *impositella* Zeller.

Family Gelechiidae

The pupae of the Gelechiidae never show any portion of the labial palpi, unless it should be a very small triangular area caudad of the labrum, between the halves of the maxillae. The prothoracic femora are never exposed (Figs. 90, 91, 92, 93, 94). The fronto-clypeal suture is always distinct and usually extends almost straight across between the proximal ends of the antennae, but occasionally each half is directed cephalad near the meson so that an angle is formed at their junction. The caudal parts of the antennae usually lie adjacent on the meson for about two fifths of their length and usually cover the caudal ends of the maxillae and sometimes of the prothoracic and mesothoracic legs. They usually separate at their distal ends to show the metathoracic legs, or what will be referred to as such in this paper. There was not enough available material in condition for dissection to determine whether the maxillae ever reached the caudal margin of the wings and overlaid the metathoracic legs, as might easily be the case. The maxillary palpi are present in all, but do not always reach the proximo-lateral angles of the maxillae. They are always reached by both prothoracic and mesothoracic legs. The wings vary somewhat in length, but are usually firmly soldered down, and the abdominal segments are somewhat depressed on the ventral surface, forming a shallow cavity into which the wings are fitted and, therefore, are not elevated above the surface of the body. There are usually very deep incisions between the segments, especially on the dorsal and ventral surfaces. Many species have the incisions deeper on the ventral surface so that the caudal end of the body may be strongly curved ventrad. The pupae are usually very active, and many of them are able to move after the fashion of click-beetles. The body is entirely covered with setae in some genera, while others have a fringe of setae along the margin of certain slightly projecting ridges and occasional depressions found usually on the seventh abdominal segment. There seems doubt as to the generic standing of the following species: *Aristotelia physaliella, Gnorimoschema lavernella*, and *Recurvaria variella*; at least they differ from other species examined in these genera. In the case of *Aristotelia* it has been impossible to determine which species is the type of the genus. The genera of Gelechiidae may be separated as follows:

a. Body setae very long and heavily chitinized, often as long as the segments of the abdomen, and, as seen under high power, usually forked at the apex; fronto-clypeal suture curving cephalad from the proximal ends of the antennae to the cephalic margin of the body; cremaster always present; dorsal cephalic margin of segments two, three, and four of the abdomen with a slight rounded projection on each side of the meson, edged with a dense fringe of whitish setae directed cephalad, caudad of this a prominent elevation bearing a similar fringe of setae on the summit (Fig. 91).

b. Dorsal surface of the cephalic margin of the movable segments with a prominent cavity on the meson having heavily chitinized edges ..... *Trichotaphe* Clemens.

bb. Dorsal surface of cephalic margin of the movable segments without any cavity; a strongly chitinized ridge separating the cephalic margin from the remainder of the segment, cephalad of this a band of short spines, then a prominent furrow, the furrow and the remainder of the cephalic margin being deeply punctate. *Ypsolophus* Fabricius.

aa. Body setae never modified; segments two, three, and four of the abdomen never as described in a.

b. Entire body with a dense covering of whitish setae visible to the unaided eye, giving the pupa a furred appearance.

c. Maxillary palpi long, reaching the proximo-lateral angles of the maxillae; antennae lying adjacent on the meson for about two fifths of their length; cremaster short and blunt, the end set with about eight stout curved setae; length 8–10 mm. *Anacampsis* Curtis.

cc. Maxillary palpi short, never reaching the proximo-lateral angles of the maxillae; antennae just meeting on the meson; cremaster with a sharp point curved dorsad, with curved setae at the sides and base; length 5–6 mm. ..... *Aristotelia* (a) Hübner.

bb. Entire body never covered with setae.

c. Seventh abdominal segment with a dense fringe of setae on some portion.

d. Fringe of setae confined to the cephalic and lateral edges of a prominent lateral cavity.

e. Body smooth, not depressed; cephalic edge of the lateral cavity trilobed (Fig. 93) ..... *Evippe* Chambers.

ee. Body with small spines, strongly depressed; cephalic edge of the lateral cavity bilobed ..... *Telphusa* Chambers.

dd. Fringe extending around the segment or nearly so.

e. Fringe extending around the segment in a straight line; body not noticeably depressed, the surface smooth. *Recurvaria* (a) Haworth.

ee. Fringe extending around the segment in a more or less wavy line; body noticeably depressed and very broad in the thoracic region, surface with punctures or spines.

f. Abdominal segments 8–10 distinctly tapering to the caudal end of the body; fringe of seventh segment extending in a wavy line around the body and edging two very large lobes on the dorsal surface.
Trypanisma Clemens.

ff. Abdominal segments 8–10 not tapering but blunt and slightly rounded at the caudal end of the body; fringe extending in a wavy line around the seventh segment, without prominent lobes on the dorsal surface.
Gelechia Hübner.

cc. Seventh abdominal segment without any fringe of setae.

d. Caudal end of body with short, stout projecting spines.

e. Caudal end of body with one such spine on the dorso-meson, projecting dorsad; fronto-clypeal suture almost straight.
Phthorimaea Meyrick.

ee. Caudal end of body with a median spine and one on each lateral margin; fronto-clypeal suture extending cephalad from the base of each antenna to the cephalic margin of the head .....*Sitotroga* Heinemann.

dd. Caudal end of body with straight or curved setae.

e. Hooked setae present at the caudal end of the body.

f. Antennae reaching the caudal margin of the wings, their caudal ends separated to show the metathoracic legs.

g. Caudal end of body with at least five long hooked setae on each side of the meson; antennae slightly enlarged at their proximal ends, making the cephalic end of the body somewhat truncate.....*Recurvaria* (b) Haworth.

gg. Caudal end of body never with more than two long curved setae on each side of the meson; cephalic end of body rounded.....*Aristotelia* (b) Hübner.

ff. Antennae never reaching the caudal margin of the wings nor separating at their caudal ends to expose the metathoracic legs .....*Gnorimoschema* (a) Busck.

ee. Hooked setae never present at the caudal end of the body; a few short, straight setae present.
Gnorimoschema (b) Busck.

The following species were examined:
Trichotaphe flavocostella Clemens
Ypsolophus citrifoliellus Chambers, *eupatoriellus* Chambers
Anacampsis sp., *rhoifructella* Clemens
Aristotelia (a) *salicifungiella* Clemens
Aristotelia (b) *physaliella* Chambers
Evippe prunifoliella Chambers
Telphusa quercinigracella Chambers, *palliderosacella* Chambers

Recurvaria (a) *apicitripunctella* Clemens
Recurvaria (b) *variella* Chambers
Trypanisma prudens Clemens
Gelechia cercerisella Chambers, *discoocellella* Chambers, *serotinella* Busck
Phthorimaea sp.
Sitotroga cerealella Olivier
Gnorimoschema (a) *lavernella* Chambers
Gnorimoschema (b) *gallaesolidaginis* Riley

Family Chrysopeleiidae

This family includes the genus Chrysopeleia which was formerly included with the Elachistidae. It has the same arrangement of parts as that in the genus Elachista but retains the fronto-clypeal suture and has no cremaster (Fig. 95). Until more is known of the relationships of this genus it seems better to place it in a family by itself. The appendages are slightly elevated and firmly soldered to each other and to the body. They extend well on to the seventh abdominal segment, so that there appears to be no motion possible between any of the body segments. There is no cremaster present and only a few short straight setae at the caudal end of the body. The abdominal spiracles are produced and tubular. The pupae are very small, being only about 3 mm. in length.

The following species was examined:
Chrysopeleia ostryaecella Chambers.

Family Oecophoridae

This family (Figs. 97 and 98) includes those pupae in which the fronto-clypeal suture is not present for its entire length and which have large maxillary palpi, usually reaching the proximo-lateral angles of the maxillae. All the species examined showed the presence of very fine setae arranged in groups over the surface of the abdomen, but these were hard to locate in Psilocorsis. The incisions between the segments are very deep in all members of the family. Of the three genera studied Psilocorsis, Agonopteryx, and Depressaria, the first seemed more nearly related to the Stenomidae, while the other two were typical gelechiids, except that the fronto-clypeal suture was never distinct. It seems probable that a revision of the group might separate these genera. The table to genera will indicate the principal differences. The body is usually strongly depressed and 5–10 mm. in length. The following table will serve to separate the genera:

a. Femora of the prothoracic legs exposed.
   b. Wings pointed, extending on to the sixth abdominal segment; proximal end of each antenna elevated and roughened with transverse ridges; cremaster present.....*Psilocorsis* Clemens.
   bb. Wings not pointed, and never extending beyond the caudal margin of the fourth abdominal segment; proximal end of each antenna never elevated or roughened with transverse ridges; cremaster never present .....*Depressaria* Haworth.
aa. Prothoracic femora never exposed.....*Agonopteryx* Hübner.

The following species were examined:
Psilocorsis obsoletella Zeller, *quercicella* Clemens
Depressaria heracliana De Geer
Agonopteryx nebulosa Zeller

Family Stenomidae

The Stenomidae include most of the genera formerly grouped under the name of Xylorictidae. The appendages are arranged as in the Gelechiidae and the maxillary palpi are minute (Fig. 96). A small portion of the labial palpi is usually apparent. The appendages are firmly soldered to each other and to the body wall. They extend slightly beyond the caudal margin of the fourth abdominal segment, so that there are three free segments, the fourth, fifth, and sixth. The margins of these free segments are serrate along the edges of the incisions, which are very deep, especially on the ventral surface, and permit the caudal end of the body to be very sharply curved ventrad, reaching almost to the caudal margin of the wings (Fig. 96a). The fronto-clypeal suture is visible for a short distance mesad of the proximal end of each antenna, but it never reaches the meson. There are many curved setae present on the ventral surface of the ninth abdominal segment. The body is always more or less depressed, and in Stenoma is about 8 mm. in length, in Menesta 3 mm. The genus Menesta, formerly included in the Gelechiidae, seems more closely allied to Stenoma and is included here. Stenoma possesses peculiarly modified setae on the body surface. These genera may be separated as follows:

a. Antennae modified at their proximal ends, forming an enlarged corrugated area; hooked setae on the ventral part of the ninth abdominal segment never on a distinct prolongation.....*Stenoma* Zeller.
aa. Antennae never modified at the proximal end; hooked setae on the ventral part of the ninth abdominal segment on a distinct prolongation .....*Menesta* Clemens.

The following species were examined:
Stenoma schlaegeri Zeller
Menesta albaciliaeella Chambers

Family Cosmopterygidae

This family name as used by most authors is equivalent to Lavernidae or Momphidae, and the genera included under all these names are usually associated with each other. The Cosmopterygidae are much more specialized, however, as they retain neither visible labial palpi nor prothoracic femora (Fig. 99). The appendages are firmly soldered to each other and to the body wall as far as the caudal margin of the sixth abdominal segment, which allows freedom of movement to this segment. There are some generalized characters present, however—the length of the first six abdominal segments, which are as long as in Yponomeutidae, and the shape of the prothorax, which is shorter on the meson than at each lateral margin. The abdominal spiracles are slightly produced and tubular. There is a very short cremaster present bearing eight hooked setae, of which four are longer than the remainder. The pupae are about 4 mm. in length.

The following species was examined:
Cosmopteryx clandestinella Busck.

Family Elachistidae

This family has been variously subdivided in the past few years, for, like the Tineidae, it included a large number of species which did not form a natural group. Some authors do not retain this family name, but as the nomenclature of the group appears to be still in a rather unsettled condition, this name is retained for the present to include the genus Elachista. The appendages are arranged as in other gelechiids, but there is no trace of maxillary palpi (Fig. 100). The surface of the body is covered with large rounded tubercles and the dorsal surface shows three distinct longitudinal elevations or ridges, one on the meson and one near each lateral margin, bearing the spiracles on the summit. The wings and other appendages are firmly soldered to each other and to the body wall, and there appear to be no free segments. The prothorax is typically gelechiid and the mesothorax shows a decided alar furrow on each side. There is a distinct cremaster present, but it shows no hooked setae. The pupae are suspended from a stem or leaf after the manner of some papilionids, with a silken girth around the body. The pupae average 3.5 mm. in length.

The following species was examined:
Elachista praelineata Braun.

Superfamily NOCTUOIDEA

This superfamily includes three families, Noctuidae, Liparidae, and Arctiidae. The Syntomidae also belong to this group, but as only one species of this family was examined and this showed no characters to separate it from the Arctiidae, the Syntomidae are not discussed as a separate family. The Noctuoidea and Bombycoidea include all the specialized families which retain labial palpi. The families of Noctuoidea may be separated thus:

a. Body seldom with setae arranged around scars of larval verrucae, if present, then the femora of the prothoracic legs exposed, or a long cremaster present bearing hooked setae at the distal end; prothoracic femora usually visible, if not, then the mesothoracic leg usually extending cephalad to the eye-pieces.....Noctuidae.

aa. Body always with setae arranged around the scars of larval verrucae; femora of the prothoracic legs never visible.

b. Maxillae never more than two fifths the length of the wings; body setae conspicuous; labial palpi usually visible.....Liparidae.

bb. Maxillae two thirds the length of the wings, or longer; body setae inconspicuous; labial palpi seldom visible.....Arctiidae.

Family Noctuidae

This family (Figs. 101, 102, 103), with a few exceptions, is characterized by the presence of labial palpi and of maxillae which extend to the caudal margin of the wing, or very closely approximate this length. Very many of the genera have a large portion of the prothoracic femora exposed. Those which do not show any portion of the prothoracic femora have the mesothoracic leg extending cephalad to the eye-pieces, with a few exceptions in the genera Homopyralis, Plusiodonta, and Anomis. Those lacking labial palpi have setae arranged around the scars of larval verrucae, as in the Arctiidae. They differ from the Arctiidae in having hooked setae on the cremaster, and in lacking flanged plates on the abdominal segments. Maxillary palpi are found in some members of the subfamilies Agrotinae, Cucullianae, and Hypeninae. Since there was not enough material available for study to furnish a basis for subfamily characters, the genera have been grouped as seemed best for purposes of classification. As far as possible the names of subfamilies as used by Hampson in the "Catalogue of Lepidoptera Phalaenae" have been adopted. This arrangement could not be followed throughout, however, and so it must be remembered that the subfamily names used here are adopted as a matter of convenience and do not stand for the genera which Hampson

grouped together. His generic and specific names have been adopted as far as possible. As to the phylogeny of the group, too little material has been examined to warrant a decided opinion on the subject. It seems probable, however, that most of the subfamilies discussed represent the ends of many lines of development. There are various stages of development found in all groups, and there are some members of each subfamily studied, except the Phytometrinae and Mominae, which show the epicranial suture.

The subfamilies mentioned above which retain maxillary palpi are undoubtedly the most generalized, the Mominae, which show neither labial palpi, prothoracic femora, maxillary palpi, nor an epicranial suture, are undoubtedly the most specialized, but nothing can be said with certainty as to the other groups. No attempt has been made to arrange the subfamilies in phylogenetic order either in the tables or in the discussion of subfamilies. The subfamilies of Noctuidae may be separated by the following table:

a. Prothoracic legs reaching cephalad to the eye-piece, mesothoracic legs never reaching as far cephalad; prothoracic femora usually visible.
  b. Cremaster, or caudal end of the body, with all the setae curved or hooked, never with any long straight setae.
    c. Setae of the cremaster usually all of the same size and length, either slightly curved or hooked; cremaster never with six or eight hooked setae of which the mesal ones are larger and longer than the remainder ..... ACRONYCTINAE.
    cc. Setae of the cremaster or caudal end of the body usually of two sizes.
      d. Body never with scars of larval verrucae bordered with setae; labial palpi and prothoracic femora always visible.
        e. Wings and maxillae produced at meson into a distinct rounded projection extending on to the fifth abdominal segment; labrum located near the cephalic end of the body: body never heavily chitinized..... PHYTOMETRINAE.
        ee. Wings and maxillae never extending beyond the caudal margin of the fourth segment; labrum in the normal position; body always heavily chitinized..... CUCULLIANAE.
      dd. Body with rounded or oval areas bordered with setae, as in the Arctiidae, especially noticeable on the dorsum of the abdomen and in the spiracular region; labial palpi and prothoracic femora never visible ..... MOMINAE.
  bb. Cremaster or caudal end of the body never with all the setae curved or hooked.
    c. Cremaster or caudal end of body with at least two long straight stout setae, 1–2 mm. in length, rarely with additional hooked setae ..... HADENINAE.

cc. Cremaster or caudal end of body never with long straight stout setae.
d. Cremaster bifurcate, narrowed at the caudal end; dorsum of movable abdominal segments with one or more rows of deep circular pits with dark, chitinized margins.....AGROTINAE.
dd. Cremaster short, broader at the distal end, very thin and plate-like, the caudo-lateral angles produced into short rounded lobes, with two or three small rounded projections between often bearing small delicate setae; dorsum of the movable abdominal segments never with pits; body strongly rugose, the abdominal segments spinose.....AGARISTINAE.
aa. Prothoracic and mesothoracic legs both reaching cephalad to the eye-piece or to the maxillary palpus where this is present; prothoracic femora seldom visible.
b. Cremaster usually present; curved or hooked setae always present at the caudal end of body, usually eight in number.
c. Body always covered with a whitish bloom.....CATOCALINAE.
cc. Body never covered with a whitish bloom.....HYPENINAE.
bb. Cremaster or setae never present at the caudal end of the body; fifth abdominal segment with a row of spines along the caudal margin extending from the sculpturing of the dorsum almost to the meson on the ventral surface .....SARROTHRIPINAE.

Subfamily *Agrotinae*

This subfamily, as here considered, includes those pupae with a stout, rugose, more or less bifurcate cremaster, and with a row of large circular pits with heavily chitinized margins along the cephalic margin of some of the abdominal segments, usually between the fourth and seventh (Fig. 101). In these pupae, the prothorax is very long, at least two thirds the length of the mesothorax, and the epicranial suture is sometimes present in the genus Agrotis. Labial palpi are always present and exposed for their entire length, and the prothoracic femora are seen in some of the genera. The mesothoracic legs, antennae, and maxillae are of practically the same length and usually extend to the caudal margin of the wings. The metathoracic legs are seldom visible and only the prothoracic legs extend cephalad to the eye-pieces, and these do not separate the sculptured eye-piece and antenna. The body is stout, and when retracted the length is about three times the width. The genera of Agrotinae may be separated as follows:

a. Femora of the prothoracic legs visible.
b. Dorsal cephalic margin of the movable abdominal segments with a single even row of pits, numbering less than fifteen; epicranial suture present; cremaster often with a row of four setae near its proximal end .....*Agrotis* Ochsenheimer.

bb. Dorsal cephalic margin of the movable abdominal segments with an interrupted row of pits numbering more than fifteen; epicranial suture never present; cremaster never with a row of four setae near its proximal end .....*Hapalia* Hübner.

aa. Femora of the prothoracic legs never visible.....*Noctua* Linnaeus.

The following species were examined:
Agrotis badinodis Grote, *bicarnea* Guenée
Hapalia incivis Guenée
Noctua clandestina Harris

Subfamily *Cucullianae*

As only two specimens of one genus, Graptolitha, were available for study, little can be said as to subfamily characters. These specimens differ from members of other subfamilies except the Catocalinae in having all the setae at the caudal end of the body hooked. There are two setae at the meson very much larger and more heavily chitinized than the remaining setae, which are usually four in number. In other respects, as the length of prothorax, size and shape of body, arrangement of appendages, presence of epicranial suture and labial palpi, exposed femora of the prothoracic legs, and traces of maxillary palpi, they resemble the Agrotinae and especially the Hadeninae as the movable abdominal segments are finely punctate along their cephalic margin.

The following species were studied:
Graptolitha laticinerea Grote, *antennata* Walker.

Subfamily *Hadeninae*

This subfamily includes pupae having stout straight setae or spines at the caudal end of the body. There are usually two, from 1–2 mm. in length, and they may be inserted in a short cremaster or directly in the caudal end of the body (Fig. 102). One genus, Cirphis, has additional slender hooked setae. The prothorax is very long, as in Agrotinae, at least two thirds the length of the mesothorax. The epicranial suture is present in the genera Polia, Hadena, Lycophotia, and Eriopus. The appendages, which in Agrotinae are of the same length and generally reach the caudal margin of the wings, are in this subfamily unequal in length. The maxillae usually reach the caudal margin of the wings, but the mesothoracic legs are shorter, and the antennae in some forms equal these or are very much shorter. Except for Cirphis and Monima the abdominal segments are punctate. These two genera have the movable abdominal segments pitted as in the

Agrotinae. The prothoracic leg extends cephalad to the eye-piece, but there is never a long point extending cephalad between the antennae and the sculptured eye-piece. The genera of Hadeninae may be separated by the following table:

a. Dorsum of movable abdominal segments with a row of deep pits along the cephalic margin.
  b. Caudal end of body with a very short cremaster ending in two straight sharp setae with four slender hooked setae at the proximal end, the hooked setae about half the length of the straight ones ..... *Cirphis* Walker.
  bb. Cremaster very short, with a long straight seta inserted in each caudo-lateral angle; hooked setae never present.
Monima Hübner.

aa. Dorsum of movable abdominal segments never with a row of deep pits along the cephalic margin.
  b. Mesothoracic leg never reaching cephalad to the eye-pieces; prothoracic femora always exposed.
    c. Caudal end of the abdomen with four closely approximated spines of the same size and shape..... *Rhodophora* Guenée.
    cc. Caudal end of body with only two spines.
      d. Spiracles noticeably modified, usually with a prominent depression near their caudal margin; spiracular opening directed somewhat caudad; cephalic third of the movable abdominal segments usually slightly elevated and densely punctate.
        e. Cremaster slender, pointed, spines closely approximated; abdominal spiracles with a darker, elevated, crescent-shaped area almost surrounding the spiracle and with a deep cavity larger than the spiracle directly caudad of it; mesothoracic spiracles not modified..... *Meliana* Curtis.
        ee. Cremaster short, blunt; area around each abdominal spiracle slightly elevated and darker in color, a prominent cavity caudad of the spiracle with a chitinized ridge along the caudal margin of the spiracle; mesothoracic spiracles also modified, the opening extending half the distance between the antennae and the meson.
          f. Chitinized ridge along the caudal margin of the abdominal spiracles distinctly serrate; clypeal region not prominently elevated and without deeply impressed lines.
Laphygma Guenée.
          ff. Chitinized ridge along the caudal margin of the abdominal spiracles not distinctly serrate; clypeal region prominently elevated and with deeply impressed lines.
Prodenia Guenée.

dd. Spiracles normal, without any prominent elevations or depressions adjacent; cephalic third of the movable abdominal segments usually not elevated; segments punctate.
e. Epicranial suture present and distinct.
f. Cephalic third of movable abdominal segments with fine punctures, the remainder of the segments smooth; no cremaster present .....*Lycophotia* Hübner.
ff. Abdominal segments all finely punctate and with wavy impressed lines, more densely punctate along cephalic margin of the movable segments; a short, distinct rugose cremaster present .....*Hadena* Schrank.
ee. Epicranial suture wanting.
f. Abdominal segments 5–7 very finely punctate on the cephalic third .....*Chloridea* Westwood.
ff. Abdominal segments with very large, shallow punctures, at least on the cephalic third of segments 4–7.
g. Abdominal segments all punctate; segments 4–7 having the punctures very large on at least the cephalic two thirds of each segment and fine punctures on the remainder .....*Pyrrhia* Hübner.
gg. Abdominal segments 1–7 punctate; segments 4–7 with larger punctures on the cephalic half of each segment and usually with finer punctures on the remainder. *Polia* Ochsenheimer.
bb. Metathoracic leg reaching to the eye-piece; cephalic margin of tenth abdominal segment with a row of deep oblong pits; prothoracic femora never exposed.....*Eriopus* Treitschke.

The following species were examined:
Cirphis unipuncta Haworth, *phragmitidicola* Guenée
Rhodophora gaurae Smith and Abbot, *florida* Guenée
Meliana albilinea Hübner.
Laphygma frugiperda Smith and Abbot
Prodenia ornithogalli Guenée
Lycophotia margaritosa Haworth
Hadena vulgaris Grote
Chloridea obsoleta Fabricius, *virescens* Fabricius
Pyrrhia umbra Hüfnagel
Polia renigera Stephens, *picta* Harris, *meditata* Grote
Eriopus floridensis Guenée
Monima alia Guenée

Subfamily *Agaristinae*

The members of this subfamily show remarkable uniformity and it is rather difficult to separate the genera. They have been given family

rank by some authors, and while the species included here differ from the typical noctuid in many respects, still no structural characters could be found to warrant their separation from the Noctuidae. The entire body surface is very rough and spinose, while the cremaster is short, broad, and decidedly flattened, with its caudo-lateral angles produced into rounded lobes, and with the caudal margin often crenulate. There are sometimes short straight setae present along the caudal margin. The antennae, mesothoracic legs, and maxillae usually reach the caudal margin of the wings, or approach it very closely. Each prothoracic leg extends cephalad to the eye-pieces. The epicranial suture is always present. The labial palpi are always visible, but the femora of the prothoracic legs are concealed except in occasional specimens. The abdominal spiracles are somewhat elevated and are surrounded by a heavy, dark, chitinized border. The openings appear to be fringed with fine setae. The genera of this subfamily may be separated as follows:

a. Antennae always reaching the caudal margin of the wings; the row of spines along the caudal margin of the abdominal segments not larger than the spines of the segment; ninth abdominal segment never with scattered spines larger than those of the other segments.
  b. Dorsum of the abdominal segments rugose and densely spinose on the first nine segments ..... *Euthisanotia* Hübner.
  bb. Dorsum of abdominal segments rugose and moderately spinose on the first seven segments; the eighth and ninth segments roughened, but with very few spines..... *Alypia* Hübner.
aa. Antennae never reaching the caudal margin of the wings; the row of spines along the caudal margin of the abdominal segments larger than those of the segment; ninth abdominal segment with scattered spines larger than those of the other segments. *Psychomorpha* Harris.

The following species were examined:
Euthisanotia grata Fabricius, *unio* Hübner
Alypia octomaculata Fabricius
Psychomorpha epimenis Drury

Subfamily *Acronyctinae*

The subfamily Acronyctinae as typified by the genus Acronycta has little to distinguish it from other subfamilies except that the cremaster is short and usually mound-like and the setae are always of the same size and length. With this genus there are here included several others, which probably do not form a natural group, though all possess cremastral setae of the same size and length and in all the

members of the group only the prothoracic legs extend cephalad to the eye-pieces. All of these genera except Acronycta have prominent projections on the head and prothorax. The epicranial suture is present only in Eulonche. The labial palpi are well developed in all and the prothoracic femora are visible only in Eulonche, Acronycta, and Achatodes. The maxillae do not reach the caudal margin of the wings in any of the genera. The metathoracic legs are always visible, and in Eulonche the mesothoracic legs are adjacent on the meson. In Plusiodonta they extend to the caudal margin of the wings, but in none of the other genera. The antennae are usually equal in length to the mesothoracic legs and never reach the caudal margin of the wings. The genus Eulonche and a few species of Acronycta are very peculiar in that there are setae on the body arranged as in Arctiidae (Fig. 103). These are easily observed on the mesothorax and the parts of the abdomen where the sculpturing is not so dense. There are also a few short spines present on the tenth segment at the base of the cremaster. The genera of Acronyctinae may be separated as follows:

a. Cephalic end of body with two large, rounded, rugose projections on the head, one on each side of the meson.
  b. Dorsum of abdomen very rugose on segments 1–7 except for a smooth caudal margin; groups of long setae present on thorax and abdomen; epicranial suture present.....*Eulonche* Grote.
  bb. Dorsum of abdomen never rugose, but with large lunate punctures on the cephalic third of segments 3–7; groups of long setae never present; epicranial suture absent.
Achatodes Guenée.

aa. Cephalic end of body with a single median projection, or without projections.
  b. Cephalic end of body with a single median projection, either on the head or prothorax.
    c. A prominent projection on the body near the cephalic margin of the prothorax; abdominal segments 1–3 with a broad smooth transverse ridge near the caudal margin; movable abdominal segments with thin flanged plates; cremaster very short and broad, with a short, stout, slightly curved seta inserted in each caudo-lateral angle .....*Homopyralis* Grote.
    cc. Projection always present on the head; setae at the caudal end of the body always hooked.
      d. Distinct cremaster not present; a large sharp point at each caudo-lateral angle of the body, with some smaller points, and three short hooked setae inserted on each side; body distinctly punctate, with a smooth band at the caudal margin

of each segment; projection on the head blunt at the end and directed ventrad.....*Plusiodonta* Guenée.

dd. Distinct cremaster present, its caudo-lateral angles produced and pointed, with two hooked setae inserted on the ventral side of each; body not punctate, slightly rugose; projection on the head narrowed to a rounded point..*Anomis* Hübner.

bb. Cephalic end of body smooth, cremastral hooks slightly curved. *Acronycta* Treitschke.

The following species were examined:

Acronycta americana Harris, *populi* Riley, *clarescens* Guenée, *hamamelis* Guenée
Eulonche oblinita Smith and Abbot
Achatodes zeae Harris
Homopyralis discalis Grote
Plusiodonta compressipalpis Guenée
Anomis erosa Hübner

Subfamily *Phytometrinae*

The members of this subfamily differ markedly from those of the other subfamilies of Noctuidae. The labrum is never in its normal position but is located near the cephalic end of the body, while the wings and maxillae extend beyond the caudal margin of the fourth abdominal segment. The wings are produced into a sharp point near the meson of the ventral surface. The labial palpi are always visible and a large portion of the prothoracic femur is exposed. The dorsal cephalic margin of the movable abdominal segments has a number of prominent furrows with slightly serrate ridges between. The prothorax is not as long as in the previously mentioned subfamilies, being only two fifths the length of the mesothorax, and the caudo-lateral angles are somewhat produced. The dorsal surface of the body shows prominent grooves along the caudal margin of the metathorax and the first four abdominal segments. The edges of these grooves are somewhat serrate. The cremaster is somewhat cylindrical and rugose, with two long hooked setae and four shorter ones. The two genera studied are very closely related and may be separated as follows:

a. Antenna reaching the caudo-lateral angle of the mesothoracic leg; cremaster with length and breadth approximately equal and longer than its longest setae.....*Phytometra* Haworth.

aa. Antenna much shorter than the mesothoracic leg and never reaching its caudo-lateral angle; cremaster always longer than broad and about equal in length to its longest setae. *Syngrapha* Hübner.

The following species were examined:
Phytometra brassicae Riley
Syngrapha falcigera Kirby

Subfamily *Mominae*

The only genus studied in this group was Charadra. This resembles the Arctiidae very much more than it does most Noctuidae in the shape of the body, in the presence of setae arranged around the scars of larval verrucae, and in the absence of epicranial suture and visible labial palpi and femora of the prothoracic legs. The antennae are broader at the proximal end than is typical in Noctuidae. The appendages are arranged more as they are in Noctuidae and there is a cremaster present, as long as the ninth and tenth abdominal segments, which bears hooked setae. The only known Arctiidae which have long cremasters are provided with flanged plates on the movable abdominal segments and the cremastral setae are never hooked. The prothoracic leg extends cephalad between the sculptured eye-piece and the antenna, but the mesothoracic leg never reaches the eye-pieces. The body is slightly punctate along the cephalic margin of the movable abdominal segments. The pupae are found in thin silken cocoons, which differ from those of the species of Arctiidae in that none of the larval hairs are used in their construction.

The following species was the only one examined:
Charadra deridens Guenée.

Subfamily *Hypeninae*

The only genus available for study of this group as given in Dyar's list was Plathypena, but as Balsa possesses the pupal characters which distinguish this from other subfamilies, it is included in the Hypeninae for the present. These characters are the presence of two long and six short hooked setae at the caudal end of the body and the fact that the prothoracic legs and the long point of the mesothoracic legs extend cephalad to the eye-piece, or, as in Balsa, to the maxillary palpus, which is always present in this genus. Plathypena shows the epicranial suture, but it is not found in Balsa. Both genera have the spiracles slightly produced, and in Plathypena they are on small elevations. The labial palpi are present in both, but the femora of the prothoracic legs are visible only in Balsa. The genera may be separated as follows:

a. Dorsum of prothorax, metathorax, and first three abdominal segments with a distinct median ridge; antennae and mesothoracic legs reaching the caudal margin of the wings and longer than the maxillae; caudal margin of mesothorax never with a row of shallow depressions ..... *Plathypena* Grote.

aa. Dorsum of body never with a median ridge; antennae and mesothoracic legs not reaching the caudal margin of the wings and not longer than the maxillae; caudal margin of mesothorax with a row of shallow depressions ..... *Balsa* Walker.

The following species were examined:
Plathypena scabra Fabricius
Balsa malana Fitch

Subfamily *Catocalinae*

This group is distinguished from all other noctuids by the presence of a whitish "bloom" on the surface of the pupa, which is retained even in alcoholic specimens. Both prothoracic and mesothoracic legs extend cephalad to the eye-pieces. The labial palpi are always present, but the femora of the prothoracic legs are seldom visible. The epicranial suture is found throughout the genera Catocala and Eunetis but is lacking in the remainder of the subfamily. The antennae, mesothoracic legs, and maxillae either reach the caudal margin of the wings or very closely approach it. The cremaster is usually very short or absent, and the setae at the caudal end of the body are usually of two sizes and inserted at different levels except in the genus Eunetis. This generic name is applied to certain species of the genus Catocala of Dyar's list which have a short cremaster, slightly broader at the caudal end, bearing about eight slightly curved setae which are usually directed towards the meson. The following table will serve to separate the genera of Catocalinae:

a. Epicranial suture present; body tapering rapidly from the fifth abdominal segment so that it is more slender in appearance than the typical noctuid, the lateral margins of abdominal segments 8–10 as seen in dorsal view convergent and not strongly convex.

b. Cremaster, if present, very short and narrowed at the caudal end, and with eight long hooked setae of two sizes, some larger and more heavily chitinized than the others..... *Catocala* Schrank.

bb. Cremaster broadened at the caudal end, usually with eight short, stout setae which are slightly curved and usually directed towards the meson ..... *Eunetis* Hübner.

aa. Epicranial suture not present; body of typical noctuid shape, with the lateral margins of abdominal segments 8–10 distinctly convex as seen in dorsal view.

b. Head with a distinct tubercle near the base of each antenna.
Euparthenos Grote.

bb. Head without a distinct tubercle at the base of each antenna.

c. Thorax and appendages with deep indeterminate transverse striations; median caudal spines of cremaster somewhat enlarged near the tip; metathoracic legs never present.
Pheocyma Hübner.

cc. Thorax and appendages approximately smooth; median caudal spines of cremaster never enlarged near the tip; metathoracic legs always apparent caudad of the maxillae.

d. Cremaster with spines practically all of the same size, no two being larger and longer than the others. . *Caenurgia* Walker.

dd. Cremaster with two spines larger and longer than the others.
Zale Hübner.

The following species were examined:

Euparthenos nubilis Hübner

Pheocyma lunifera Hübner

Caenurgia erechtea Cramer, *crassiuscula* Haworth

Zale calycanthata Smith and Abbot, *lunata* Drury

Catocala illecta Walker, *unijuga* Walker, *briseis* Edwards, *verecunda* Hulst, *aholibah* Strecker, *ilia* Cramer, *innubens* Guenée, *neogama*, Smith and Abbot, *pacta* Linnaeus, *sponsa* Linnaeus

Eunetis blandula Hulst, *ultronia* Hübner, *grynea* Cramer

Subfamily *Sarrothripinae*

This group is readily distinguished because it has neither cremaster nor setae at the caudal end of the body, which is probably due to the fact that its members are found in thick cocoons. The dorsal surface of the body is very irregularly rugose with spinous elevations, and there is a distinct row of spines along the caudal margin of the fifth abdominal segment extending from the rugose area on the dorsum around nearly to the meson of the ventral surface. A few spines are present in a similar position on the fourth abdominal segment. The epicranial suture is always present, the labial palpi are visible for their entire length, and only a small portion of the prothoracic femur is exposed, or it may be entirely concealed. The maxillae never reach the caudal margin of the wings, being about seven eighths of their length, with the mesothoracic legs meeting just caudad of them. The antennae always reach to the caudal margin of the wings, while the mesothoracic legs do not, but the latter are slightly longer than the maxillae. Both prothoracic and mesothoracic legs extend cephalad to the eye-piece, the mesothoracic legs extending between the sculptured eye-piece and the antenna.

The members of this subfamily have been treated as the family Nycteolidae by some authors, but there is no evidence in the pupae to separate them from the family Noctuidae.

The following species were examined:
Sarrothripus revayana Scopoli, *proteella* Dyar.

Family Arctiidae

The members of this family all possess distinct setae arranged around the scars of the larval verrucae. These setae are seldom conspicuous enough to be seen with the naked eye as in Liparidae, but are easily visible with the aid of the microscope. The labial palpi are never visible, unless as small triangular areas caudad of the labrum, except in Halisidota, where they are exposed for their entire length. The femora of the prothoracic legs are never visible. The shape of the body is characteristic, being slightly concave on the dorsum in the region of the metathorax (Fig. 104). Certain genera of Noctuidae, Acronycta, Eulonche, and Charadra, also show setae arranged around the scars of the larval verrucae. In the two genera first named, both labial palpi and prothoracic femora are exposed, while Charadra possesses a long cremaster bearing hooked setae. Those genera of Arctiidae with a cremaster never have hooked setae, but all cremastral setae are flattened at the distal end. The epicranial suture is never present in any member of this family. The prothorax is usually long, often half the length of the mesothorax as in most Noctuidae. The genus Ctenucha, included with the Syntomidae in Dyar's list, shows no characters to distinguish it from the Arctiidae and it is probable that other genera of this family should be included here. The genera of Arctiidae may be separated as follows:

a. Abdominal segments 5–7 never with a flanged plate along the cephalic margin, or with deep furrows between these segments when the body is retracted; maxillae nearly as long as the wings; mesothoracic wings never meeting on the meson caudad of the appendages.
  b. Dorsal surface of abdomen flattened; body broadly rounded at caudal end and bearing a row of short setae which are slightly curved at tip; body brown, concolorous.
    c. Labial palpi showing for about one sixth of the length of the maxillae; body 18–20 mm. in length; dorsal surface of abdomen never with depressed areas ..... *Halisidota* Hübner.
    cc. Labial palpi never showing except as a small triangular piece about a millimeter in length; body 12–15 mm. in length; dorsal surface of abdomen with depressed areas on meson of each segment at cephalic margin and one on each side adjacent to the spiracles ..... *Euchaetias* Lyman.

bb. Dorsal surface of abdomen not flattened; body tapering at caudal end; color yellowish or chestnut-brown, strikingly marked with black.

c. Distinct cremaster present.....*Haploa* Hübner.

cc. Distinct cremaster never present.

d. Antennae about seven eighths the length of the wings; maxillae never reaching the caudal margin of the wings.
Utetheisa Hübner.

dd. Antennae as long as the wings; maxillae always reaching the caudal margin of the wings.....*Ctenucha* Kirby.

aa. Abdominal segments 5–7 with a flanged plate along the cephalic margin, and with deep furrows between the movable segments when the body is retracted; maxillae never as long as the wings, usually about two thirds the length; mesothoracic wings always meeting on the meson caudad of the appendages.

b. Abdominal segments 4–6 with a similar flanged plate adjacent to the caudal margin of the segment.

c. Appendages, and usually the thorax, roughened with indeterminate transverse striations; abdominal segments densely, coarsely punctate.

d. Head with a small tubercle at the proximal end of each antenna; antennae always much shorter than the prothoracic legs .....*Estigmene* Hübner.

dd. Head without a tubercle at the proximal end of each antenna; antennae as long as, or longer than, the prothoracic legs.

e. Body usually 18–20 mm. in length, stout; setae of the cremaster of various sizes and lengths, the shortest ones only about half the length of the longest, and irregularly arranged, always fifteen or more in number.
Diacrisia Hübner.

ee. Body seldom over 12 mm. in length, varying from 10–15 mm., rather slender; setae of the cremaster of practically the same size and length, arranged in two transverse rows, with four in the dorsal and eight in the ventral row, never as many as fifteen in number .....*Hyphantria* Harris.

cc. Thorax and appendages smooth and polished; body sparsely, finely punctate .....*Ecpantheria* Hübner.

bb. Abdominal segments 4–6 never with a flanged plate adjacent to the caudal margin.

c. Distinct cremaster always present and long, bearing setae at the caudal end; antennae about equaling the maxillae in length, usually three fourths the length of the wings.
Apantesis Walker.

cc. Distinct cremaster never present; a row of setae at the caudal end of the body; antennae very much shorter than the maxillae, being about half the length of the wings....*Isia* Walker.

The following species were examined:
Halisidota tessellaris Smith and Abbot, *caryae* Harris
Euchaetias egle Drury
Haploa clymene Brown
Utetheisa bella Linnaeus
Ctenucha virginica Charpentier
Estigmene acraea Drury
Diacrisia virginica Fabricius
Hyphantria cunea Drury
Ecpantheria deflorata Fabricius
Apantesis virgo Linnaeus, *michabo* Grote, *arge* Drury, *phyllira* Drury, *nais* Drury
Isia isabella Smith and Abbot

Family Liparidae

This family, like the Arctiidae, is characterized by the presence of setae arranged around the scars of the larval verrucae. In the Liparidae the setae are long and coarse, and easily visible to the unaided eye. With the exception of Porthetria all the genera examined show a characteristic arrangement of appendages (Fig. 105). In Porthetria the labial palpi were usually concealed by the maxillae, although a large number of pupae show them present, as in Figure 105. The epicranial suture is never present. The maxillae are always short, never more than two fifths the length of the wings. The legs are usually shorter than in most pupae, the mesothoracic legs never reaching the caudal margin of the wings. The antennae are pectinate and are longer and broader in the male than in the female. The cremaster is always present, smooth, longer than broad, and bears short hooked setae at the distal end.

Most of the species examined show a remarkable uniformity of characters, and considerable difficulty was encountered in separating the genera. The difficulty lies in the fact that there is considerable difference between the sexes, not only in the length and breadth of the antennae, but in the size and arrangement of other appendages. In Hemerocampa the adult females are apterous, and the wings in the pupa are not as long as in the males. The wings of the females reach slightly over the cephalic margin of the fourth abdominal segment, while in the male they reach to the caudal margin of that segment. In Hemerocampa the dorsum of the first three abdominal segments is covered on each side of the meson with small vesicles. The following table will serve to separate the genera of Liparidae:

a. Spiracular furrows never present on the cephalic margin of the movable abdominal segments; labial palpi present and well developed; long setae not present on the face-parts near the caudal margin of the head, on the clypeus, or on the sculptured eye-pieces.
  b. Labial palpi about equal in width to each maxilla; cremastral setae about one third the length of the cremaster.
    c. Dorsal surface of abdomen densely covered with long setae; body brown, concolorous except sometimes for the lighter transverse conjunctiva; antennae with the stem of the flagellum very broad and distinctly elevated.
      d. Abdominal segments 8–10, in dorsal view, distinctly narrowed and tapering; clypeus and labrum on a level with the other face-parts; cremaster directed caudad; antennae of male reaching about half the distance along the mesothoracic legs, and distinctly pointed .....*Dasychira* Stephens.
      dd. Abdominal segments 8–10, in dorsal view, not narrowed and distinctly tapering; clypeus and labrum both elevated above the level of the other face-parts; cremaster directed dorsad; distal half of the antennae of the female distinctly narrowed and pointed, reaching about half the distance along the mesothoracic legs .....*Olene* Hübner.
    cc. Dorsal surface of abdomen not very densely covered with setae; body white variously marked with brown, or vice versa; antennae in both sexes with the stem of the flagellum scarcely indicated and the distal end always rounded, in the male extending about half the length of the wings and curved mesad so that they often meet, in the female never reaching half the distance along the mesothoracic legs and never meeting on the meson.
Hemerocampa Dyar.
  bb. Labial palpi only half the width of each maxilla; cremastral setae about half the length of the cremaster; antennae in the male broad for almost their entire length and extending about three fourths the length of the wings, adjacent or meeting on the meson, in the female pointed at the distal end and reaching about half the distance along the mesothoracic legs.
Euproctis Hübner.
aa. Spiracular furrows always present on the cephalic margin of the movable abdominal segments and extending almost to the meson, five or six in number and separated by sharply carinate ridges; caudal portion of face-parts, clypeus, and sculptured eye-pieces with coarse setae similar to those on the body, labial palpi often concealed, but sometimes visible as in the remainder of the family.
Porthetria Hübner.

The following species were examined:
Dasychira pudibunda Linnaeus
Olene manto Strecker

Hemerocampa leucostigma Smith and Abbot
Porthetria dispar Linnaeus
Euproctis chrysorrhoea Linnaeus

Superfamily BOMBYCOIDEA

This superfamily includes those families in which the body is more or less densely covered with setae and which usually retain the labial palpi. They seem to be more nearly related to the Saturnioidea than to any other superfamily, although the Lasiocampidae show certain points of relationship with the Liparidae. All the members of the superfamily, so far as known, are found in thick silken cocoons, much like those of the Saturniidae. The families of Bombycoidea may be separated as follows:

a. Epicranial suture present; labial palpi visible.....Lasiocampidae.
aa. Epicranial suture never present; labial palpi concealed by the maxillae except for a small triangular area at the proximal end.
Bombycidae.

Family Lasiocampidae

The members of this family usually have mouth parts and appendages arranged as in the Liparidae (Fig. 106). The epicranial suture is always present and the vertex is longer than that found in any but the more generalized forms. The maxillae are short, never more than one third the length of the wings, and extend very slightly beyond the distal ends of the labial palpi, or may be shorter than the palpi.

The antennae are broad and pectinate, and never extend as far caudad as the prothoracic legs. The coxae of the prothoracic legs and sometimes of the mesothoracic pair are often visible caudad of the maxillae and labial palpi. The prothoracic legs are slightly more than half the length of the wings and the mesothoracic legs never reach the caudal margin of the wings. The setae of the body are very conspicuous except in Tolype, but are not arranged around the scars of the larval verrucae. The movable segments are capable of being retracted till only their caudal margins are visible. There is never a cremaster present, and there are no hooked setae at the caudal end of the body. The body is broadly rounded at the caudal end and the body setae are usually a little longer and coarser in this region. This family is considered by many authors to be more specialized than any of the Saturnioidea, but the presence of the epicranial suture and exposed labial palpi shows that they are much more generalized. The genera of Lasiocampidae may be separated as follows:

a. Entire surface of body except the appendages with a dense covering of fine short setae, giving it a furred appearance; abdominal segments 8–10 considerably narrower than the remainder of the abdomen .....*Malacosoma* Hübner.

aa. Entire surface of body except appendages never with a dense covering of setae giving it a furred appearance, either with a very sparse covering, or without visible setae; abdominal segments 8–10 not noticeably narrower than the remainder of the abdomen.

b. Body sparsely covered with very fine short setae except at the caudal end, where they are longer and coarser; tenth segment broadly rounded at the caudal end.

c. Lateral surface of abdomen on either side of the spiracles with setae much thicker than on the dorsum; dorsal surface of abdomen very coarsely punctate .....*Lasiocampa* Schrank.

cc. Lateral surface of abdomen on either side of the spiracles never with the setae more numerous than on the dorsum; dorsal surface of abdomen very finely punctate....*Cosmotriche* Hübner.

bb. Body without any visible covering of setae; tenth segment abruptly narrowed at the caudal end, suggesting a cremaster. *Tolype* Hübner.

The following species were examined:
Malacosoma americana Fabricius, *disstria* Hübner
Lasiocampa quercus Linnaeus (Europe)
Cosmotriche potatoria Linnaeus (Europe)
Tolype velleda Stoll

Family Bombycidae

This family includes the genus Bombyx, which is domesticated in various parts of the world (Fig. 107). The body is covered with rather coarse short setae which are somewhat longer at the caudal end of the body. The epicranial suture is never present. The appendages are arranged much as in Lasiocampidae. The labial palpi are almost concealed, being overlaid by large ovate appendages, appearing to be heavily veined, which are presumably the maxillae (no dissections were made of this species). The mandibles are represented by strongly elevated tubercles. The coxae of one pair of legs, probably the mesothoracic, are adjacent on the meson caudad of the maxillae. The legs are short, and both prothoracic and mesothoracic pairs lie adjacent on the meson. The antennae are pectinate, broad at the proximal end and rapidly narrowed, ending in a point opposite the distal ends of the prothoracic legs. The mesothoracic wings lie adjacent on the meson caudad of the mesothoracic legs. The movable segments may be retracted so that only their caudal margins are visible. There is no cremaster present. The pupa strongly re-

sembles those of certain species of Saturniidae and it is quite probable that they had a common ancestor, although the Bombycidae are undoubtedly more generalized. The only species in America is *Bombyx mori* Linnaeus.

Superfamily NOTODONTOIDEA

The families included here never have the entire labial palpi exposed, but a very small triangular or polygonal area is sometimes visible just caudad of the labrum. Some genera of Geometridae have the prothoracic femora exposed, while the epicranial suture is present in some of the members of each family. Although the larvae of Geometridae are easily recognized and are very readily distinguished from those of the Notodontidae, the pupae show much closer relationships, and it is difficult to draw a hard and fast line between the two families. The three families included here have probably had a common ancestor, and although the Dioptidae retain the epicranial suture they must be considered the most specialized, as both Geometridae and Notodontidae show more generalized characters in some of their genera. The following table may be used to separate the families of Notodontoidea:

a. Antennae never extending beyond the caudal margin of the wings; dorsum of abdomen never with a prominent hooked seta on each side of the meson of segments 7–10.

b. Maxillae usually more than three fifths the length of the wings, if not, then the caudal end of the body with hooked setae, or the spiracles of the third abdominal segment concealed by the wings and those of the sixth segment farther ventrad than those of the other segments; prothoracic femora often exposed; a deep furrow usually present on the dorsum of the abdomen between the ninth and tenth segments; caudal margin of mesothorax never with a row of deep pits with smooth tubercle-like areas between. ..... Geometridae.

bb. Maxillae seldom exceeding three fifths the length of the wings, if so, then the caudal margin of the mesothorax with a row of deep pits with smooth, elevated, quadrangular tubercle-like areas between them; or with the entire body surface coarsely punctate; abdominal spiracles of the third segment never concealed by the wings, and those of the sixth never farther ventrad than the remainder; prothoracic femora never exposed; a furrow never present on the dorsum of the abdomen between segments 8 and 9 except in Datana, where the cremaster is of the type shown in Figure 112 ..... Notodontidae.

aa. Antennae extending beyond the caudal margin of the wings; dorsum of abdomen with a prominent hooked seta on each side of the meson of segments 7–10 ..... DIOPTIDAE.

Family GEOMETRIDAE

The pupae in this family (Figs. 108 and 109) never have the labial palpi exposed except as small triangular or polygonal areas caudad of the labrum. The maxillary palpi are never present. The epicranial suture is present in some of the genera in Groups A and C. Some of the genera have the femora of the prothoracic legs exposed. In all the genera examined, either the prothoracic or mesothoracic leg, or sometimes both, extended cephalad between the sculptured eye-piece and the antenna. The prothoracic and mesothoracic legs are longer than is usual in most families, the former being usually three fourths the length of the wings, while the latter always extend to the caudal margin of the wings. Many of the genera show the fronto-clypeal suture extending from the proximal ends of the antennae and directed caudad towards the invaginations for the anterior arms of the tentorium. The suture is very distinct for the cephalic part and is often indicated by a slight furrow for the remainder of the distance. In the genus Haematopsis there is a prominent cephalic projection bearing hooks which hold the suspensory threads, as this pupa is not found in a cocoon. The antennae vary little throughout the family, and are generally equal in width to, or wider than, the prothoracic legs, usually extending to the caudal margin of the wings. The mesothoracic wings usually extend farther caudad than in the nearly related families, reaching almost to the caudal margin of the fourth abdominal segment, although not visible in ventral view. The mesothorax is very short in some genera, particularly in those of Group D, where it is never twice the length of the prothorax. The mesothoracic spiracles very often have a decided projection adjacent to their caudal margin, which is usually flattened or tuberculate in form and often covered with very fine short setae. The abdominal spiracles are sometimes produced, and in nearly all genera the sixth spiracle, and sometimes the seventh also, is considerably farther ventrad than the remainder. The abdomen is usually coarsely punctate, sometimes roughened with deep transverse striations. A cremaster of some kind is always present. One of the most interesting structures of the abdomen is the dorsal furrow between the ninth and tenth segments. This is usually deep and fringed with very fine setae. This furrow frequently projects caudad on the lateral surface of the body and this portion is often separated from the dorsal furrow. This dorsal fur-

row is present in all members of Group A except Ennomos and in a few members of Group D. These dorsal furrows are found in other families, notably in the Gelechiidae and some Pyralididae.

The attempt to classify the pupae of Geometridae was seriously hampered by lack of material. Reared material was very hard to obtain, as the larvae develop slowly and seem to be very susceptible to disease. The available material, moreover, did not seem to fall in with any of the existing schemes of classification, so that the only practical solution of the difficulty was to divide them into groups according to the pupal characters. These may or may not be natural groups, but they will serve to indicate relationships in some degree. According to the pupal characters there seem to be two large divisions, one with hooked setae on the cremaster, the other without them. As the presence of hooked setae is a more generalized character, the groups in which they are present should be the more generalized, and the presence of the epicranial suture strengthens this view. Group A includes representatives of the subfamilies Sterrhinae, Ennominae, and Hydriomeninae as listed by Dyar. Group B includes for the present only the genus Haematopsis. Group C includes the genera Alsophila and Brephos, which are similar in many respects and possess the same type of cremaster. This must also be considered as a generalized group since the epicranial suture is present in Alsophila. Brephos has usually been considered as the most generalized geometrid, but no epicranial suture has been located. The maxillae are also much shorter in Alsophila. In Group D the epicranial suture is never present. Spiracular furrows are frequently found in Groups A and D. The adult females of some of the geometrid species are apterous. Although abundant material of one such species, *Paleacrita vernata,* was examined, the pupal wings were found as well developed in the female as in the male. These groups of Geometridae may be separated as follows:

a. Cremaster with hooked setae.
   b. Setae of the cremaster always of two sizes, usually either the two or four farthest caudad much larger than the others; dorsum of abdomen usually with a deep furrow between abdominal segments 9 and 10; body never with a bifurcate projection at the cephalic end ..... GROUP A.
   bb. Setae of the cremaster always of the same size; dorsum of abdomen never with a furrow between segments 9 and 10; body with a long bifurcate projection at the cephalic end, densely covered with hooked setae ..... GROUP B.

aa. Cremaster never with hooked setae.
b. Cremaster a stout T-shaped spine.....GROUP C.
bb. Cremaster always bifurcate .....GROUP D.

Group A

This group includes species in which the cremastral setae are of two sizes, and which generally show the epicranial suture, and a dorsal furrow between the ninth and tenth abdominal segments (Fig. 109). Spiracular furrows are also frequently present. The genera included in this group may be separated as follows:

a. Epicranial suture always present; prothoracic femora always exposed, usually a large portion; spiracular furrows never present; dorsum of abdomen with a distinct furrow between segments 9 and 10, and also on the lateral surface of segment 10.
b. Dorsum of fifth abdominal segment with a distinct furrow on the cephalic margin; caudal margin of the furrow between the ninth and tenth abdominal segments with finely serrate edges and without setae .....*Hydria* Hübner.
bb. Dorsum of fifth abdominal segment never with a distinct furrow on the cephalic margin; caudal margin of the furrow between the ninth and tenth abdominal segments coarsely serrate.
c. Prothoracic and mesothoracic legs extending cephalad between the sculptured eye-piece and the antenna, the mesothoracic leg extending almost as far cephalad as the prothoracic; caudal margin of the furrow between the ninth and tenth abdominal segments without setae; cremaster distinctly constricted at the proximal end and circular in outline.....*Eois* Hübner.
cc. Prothoracic leg extending cephalad between the sculptured eye-pieces and the antenna, the mesothoracic leg never reaching farther cephalad than the caudal margin of the eye-piece; caudal margin of the furrow between the ninth and tenth abdominal segments usually fringed with fine setae; cremaster not constricted at the proximal end, triangular in outline.
d. Cremaster with hooked setae of nearly the same size, the median caudal setae being only slightly larger than the others; three setae inserted along each side of the cremaster, the other two cephalad of these and slightly mesad.
Tephroclystis Hübner.
dd. Cremaster with the hooked setae of widely differing sizes, the two median caudal setae being much larger and longer than the others, a smaller seta adjacent on each side, while the other setae are arranged in a tranverse row just cephalad of the caudal setae.....*Cinglis* Guenée.

aa. Epicranial suture never present.
b. Prothoracic femora exposed, but only a very narrow portion.
c. Spiracular furrows present on the fifth abdominal segment; ventral surface of head with a prominent transverse ridge extending from about the middle of the glazed eye-piece; body setae arising from small dark brown or black papillae..*Philobia* Duponchel.
cc. Spiracular furrows never present on the fifth abdominal segment; ventral surface of head never with a transverse ridge; body setae arising from small pits.....*Sabulodes* Guenée.
bb. Prothoracic femora never exposed.
c. Antennae distinctly elevated and covered with five or six rows of small round tubercles; distinct ridges or flanged plates present along both margins of the movable segments.
d. Cremaster with the two median caudal spines very much larger than the others; distinct furrow always present between the ninth and tenth abdominal segments; color dark brown.
Nacophora Hulst.
dd. Cremaster with the four caudal spines about the same size and much larger than the others; distinct furrow never present between the ninth and tenth abdominal segments; color usually white, sometimes partly brown.
Ennomos Treitschke.
cc. Antennae elevated but never with distinct rows of tubercles; ridges or flanged plates never present on the movable segments.
d. Maxillae about two thirds the length of the wings; prothoracic mesothoracic, and metathoracic legs all meeting on the meson caudad of the maxillae.....*Xanthotype* Warren.
dd. Maxillae always more than two thirds the length of the wings; prothoracic and -mesothoracic legs never meeting on the meson caudad of the maxillae.
e. Spiracular furrows present on the cephalic margin of the fifth abdominal segment, with more or less interrupted ridges between; cremaster with the four caudal setae always larger than the others.....*Ania* Stephens.
ee. Spiracular furrows never present on the cephalic margin of the fifth abdominal segment, cremaster with two caudal setae larger than the others.....*Cingilia* Walker.

Group B

The pupae of this group are easily distinguished by the long bifurcate projection at the cephalic end of the body, which is covered with hooked setae. There are never spiracular furrows present on the cephalic margin of the movable segments. The mesothoracic legs meet on the meson caudad of the maxillae. The body is very slender and never punctate. This group includes the genus Haematopsis.

Group C

The species of this group are distinguished by the peculiar T-shaped cremaster. The genera may be separated as follows:

a. Epicranial suture present; prothoracic and mesothoracic legs meeting on the meson caudad of the maxillae.....*Alsophila* Hübner.
aa. Epicranial suture never present; prothoracic and mesothoracic legs never meeting on the meson caudad of the maxillae.
Brephos Ochsenheimer.

Group D

This group is characterized by the presence of a bifurcate cremaster. The epicranial suture is never present, but a portion of the prothoracic femora is exposed in many genera. The following table will serve to separate the genera of this group:

a. Prothoracic femora visible.
  b. Cephalic margin of the fifth abdominal segment with one deep spiracular furrow with strongly chitinized edges, just cephalad of each spiracle.
    c. Mesothoracic spiracle with a broad, very strongly elevated ridge or oval tubercle adjacent to its caudal margin which is covered with fine short setae; surface of spiracular furrow with distinct punctures .....*Physostegania* Warren.
    cc. Mesothoracic spiracle with only a very narrow, slightly elevated ridge adjacent to its caudal margin, usually covered with setae; surface of spiracular furrow without distinct punctures.
      d. Dorsal surface of abdomen never with a distinct furrow between the ninth and tenth segments, its caudal margin finely serrate; surface of the spiracular furrow almost smooth.
Ectropis Hübner.
      d. Dorsal surface of abdomen never with a distinct furrow between the ninth and tenth segments; surface of the spiracular furrows strongly rugose.....*Cleora* Curtis.
  bb. Fifth abdominal segment without any deep spiracular furrow; cephalic margin of the segment deeply punctate, the punctures sometimes confluent; mesothoracic spiracle with a broad strongly elevated ridge or tubercle adjacent to its caudal margin; dorsal surface of abdomen without a distinct furrow between the ninth and tenth segments....*Cymatophora* Hübner.
aa. Prothoracic femora never visible; deep spiracular furrows always present on the cephalic margin of the fifth abdominal segment; mesothoracic spiracle always with a prominent elevation adjacent to its caudal margin.
  b. Dorsal surface of abdomen never with a furrow between the ninth and tenth segments; abdominal spiracles very strongly produced;

cremaster often showing two lateral setae on each side near the proximal end.

bb. Dorsal surface of abdomen with a distinct furrow between the ninth and tenth segments, its caudal margin coarsely serrate; a prominent lateral depression or furrow present on the lateral surface of the tenth abdominal segment.

c. Maxillae four fifths the length of the wings or less; mesothoracic legs meeting on the meson just caudad of the maxillae; antennae more than twice as wide at the proximal as at the distal end ..... *Lycia* Hübner.

cc. Maxillae always more than four fifths the length of the wings; mesothoracic legs never meeting on the meson caudad of the maxillae; antennae of almost the same width throughout, never twice as wide at the proximal as at the distal end. *Erannis* Hübner.

The following species were examined:

Group A

Hydria undulata Linnaeus
Eois inductata Guenée
Tephroclystis interruptofasciata Packard, *absinthiata* Clerck
Cinglis similaria Walker
Philobia enotata Guenée
Sabulodes lorata Grote, *transversata* Drury
Nacophora queruaria Smith and Abbot
Ennomos subsignarius Hübner, *magnarius* Guenée
Xanthotype crocataria Fabricius
Ania limbata Haworth
Cingilia catenaria Drury
Cosymbia serrulata Packard

Group B

Haematopsis grataria Fabricius

Group C

Alsophila pometaria Harris
Brephos infans Möschler

Group D

Physostegania pustularia Guenée
Ectropis crepuscularia Denis and Schiffermueller
Cleora pampinaria Guenée
Cymatophora ribearia Fitch
Paleacrita vernata Peck
Lycia cognataria Guenée
Erannis tiliaria Harris

Family Notodontidae

The pupae of this family never show more than a small triangular or polygonal proximal portion of the labial palpi, and maxillary palpi are never present. The femora of the prothoracic legs are never exposed. The epicranial suture is present in the genera Apatelodes and Melalopha. The maxillae never reach the caudal margin of the wings. The antennae are always widest at their proximal ends, and there the width exceeds the greatest width of the prothoracic legs. Each antenna tapers gradually to a pointed tip and the tips often lie adjacent on the meson caudad of the other appendages. The metathoracic legs are seldom visible. The mesothoracic leg never reaches cephalad to the eye-pieces. The abdomen is always punctate and in most species the punctures are large. A cremaster is usually present and there are various types, as in Figures 111, 112, 113. Packard divided the Notodontidae into six subfamilies. The pupae examined show that these subfamilies are well founded, but only tables to genera are given here as so few species of Notodontidae were examined. The genera Schizura and Heterocampa are not well defined and the species are separated with difficulty. The species are listed, however, under the subfamily name.

Some authors believe that the genus Apatelodes belongs to the European family Eupterotidae, and is incorrectly listed with the Notodontidae. As no pupae of Eupterotidae have been examined, it is impossible to say whether pupal characters would justify this change. There are, however, no pupal characters as far as observed, which would prevent its being included with the Notodontidae. The two species differ widely and are possibly not congeneric. The following tables will serve to separate the genera of Notodontidae:

a. Maxillae one third, or less, the length of the wings; both prothoracic and mesothoracic legs meeting on the meson caudad of the maxillae; abdomen very finely punctate.
  b. Thorax and abdomen thickly covered with very fine, short setae; cremaster a stout spine about one millimeter in length with two short recurving hooks at the tip, each of which bears two or more very fine setae..... *Melalopha* Hübner.
  bb. Thorax and abdomen never thickly covered with fine, short setae; cephalic margin of first abdominal segment without tubercles; cremaster never as described above, sometimes absent.
    c. Abdominal segments 2–7 with distinct flanged plates at both cephalic and caudal margins, the cephalic plate interrupted by deep pits, giving it the appearance of a row of square tubercles; appendages not at all elevated, making a smooth even

surface; cephalic end of body not elevated between the antennae; short cremaster sometimes present.

Apatelodes Packard.

cc. Abdominal segments 2–7 never with flanged plates; appendages distinctly elevated; cephalic end of body elevated between the antennae; cremaster never present.

Harpyia Ochsenheimer.

aa. Maxillae always more than one third the length of the wings; never with both prothoracic and mesothoracic legs meeting on the meson; abdomen usually rather coarsely punctate.

b. Maxillae from one half to three fifths the length of the wings; mesothoracic legs meeting on the meson caudad of the maxillae; appendages roughened with deep indeterminate striations; abdominal segments coarsely punctate; a distinct, deep furrow on the dorsum between the ninth and tenth abdominal segments; cremaster short, bifurcate, each half with several short spiny processes, usually directed laterad.....*Datana* Walker.

bb. Maxillae more than three fifths the length of the wings; neither prothoracic nor mesothoracic legs meeting on the meson caudad of the maxillae; appendages usually with shallow indeterminate striations; a distinct furrow never present on the dorsum between the ninth and tenth abdominal segments; cremaster not as described above.

c. Entire body surface with coarse, deep punctures; cephalic margin of the movable abdominal segments with large lunate punctures and a distinct ridge with a row of large, very distinct punctures just caudad of the ridge; cremaster short, rugose, slightly bifurcate, bearing six long hooked setae; mesothorax never with a deeply pitted caudal margin.

Symmerista Hübner.

cc. Body usually punctate on the abdomen, but not on the appendages; movable abdominal segments sometimes with a slight ridge along the cephalic margin, but never with a distinct row of large punctures caudad of the ridge; cremaster bifurcate, but never with hooked setae; mesothorax with a row of deep pits along its caudal margin with smooth quadrangular areas between, and partly covering them.

d. First abdominal segment with a small tubercle on each side of the meson at the cephalic margin of the segment; entire dorsal surface of the tenth segment distinctly elevated and very rugose; points of the cremaster divergent.

Hyparpax Hübner.

dd. First abdominal segment without tubercles; entire dorsal surface of the tenth segment not elevated and rugose.

e. Wings always touching on the meson; maxillae never as long as the wings; cephalic end of body sometimes with two sharp, heavily chitinized spinous projections.

Schizura Doubleday.

ee. Wings adjacent on the meson but not touching; maxillae usually as long as the wings; cephalic end of body without heavily chitinized spinous projections.
Heterocampa Doubleday.

The following species were examined:

Melalophinae

Melalopha inclusa Hübner, *apicalis* Walker, *albosigma* Fitch

Apatelodinae

Apatelodes torrefacta Smith and Abbot, *angelica* Grote

Cerurinae

Harpyia borealis Boisduval

Pygaerinae

Datana ministra Drury, *modesta* Beutenmüller, *angusii* Grote and Robinson, *chiriquensis* Dyar, *contracta* Walker, *drexelii* Hy. Edwards, *integerrima* Grote and Robinson, *major* Grote and Robinson, *palmii* Beutenmüller, *robusta* Strecker

Notodontinae

Symmerista albifrons Smith and Abbot

Heterocampinae

Hyparpax aurora Smith and Abbot

Schizura ipomoeae Doubleday, *concinna* Smith and Abbot, *unicornis* Smith and Abbot

Heterocampa guttivitta Walker, *bilineata* Packard

Family Dioptidae

The pupae of this family closely resemble those of the Geometridae, but are more specialized than most of the genera in that family, although they show the epicranial suture (Fig. 115). The appendages are arranged very much as in the Geometridae, but there is no trace of labial palpi, maxillary palpi, or prothoracic femora (Fig. 114). The antennae are filiform, extending beyond the caudal margin of the wings and about half way down on to the fifth abdominal segment. Each prothoracic leg extends cephalad between the sculptured eye-piece and the antenna. The distal ends of the prothoracic and mesothoracic legs and the maxillae are overlaid by the antennae, which lie adjacent on the meson at their distal ends. The abdomen is elevated at the dorso-meson to form a low ridge, and there are prominent hooked setae present on segments seven to ten as well as on the cremaster. This family contains a single American species, *Phryganidia californica* Packard. The family has usually been placed between the Noctuidae and Notodontidae, and widely separated from the Geometridae. The pupa shows no relationship to the noctuids, and is much more highly specialized than most members of that family.

Superfamily SPHINGOIDEA

The members of this superfamily retain but one generalized character, the presence of exposed portions of the prothoracic femora in some of the more generalized forms. The shape of the pupa is almost as distinctive as that of the larva, being usually fusiform, often with the head distinctly narrower than the thorax, giving the body a "shouldered" appearance. The epicranial suture is never present, the only distinct head suture remaining being that adjacent to the proximal end of each antenna. The wings and maxillae are unusually long in most members of this superfamily and various means are taken to accomodate the extra length, particularly of the maxillae. The fourth abdominal segment is usually longer on the ventral surface than on the dorsal, and the wings are seldom broadly rounded at their caudal margins, but usually somewhat pointed. The position of the head is also changed in many species and found almost, or entirely, on the dorsal surface of the body. The mandibles are often very conspicuous, being represented by strongly elevated tubercles. The prothoracic legs are usually about half the length of the wings and the mesothoracic legs three fourths of their length. The metathoracic legs are seldom visible. The antennae are for the most part filiform and vary from two fifths to three fourths the length of the wings. In the genera Smerinthus, Paonias, Marumba, and Cressonia the antennae are considerably wider at their proximal end and slightly pectinate, being larger and longer in the male, and the whole appearance of the body reminds one strongly of the Saturniidae. These genera are in many respects the most specialized of the Sphingoidea, and some of them are found in cocoons. It is an interesting fact that the most specialized forms in nearly all of the subfamilies of Sphingidae examined, show relationship to the Saturniidae. This group is therefore considered as related to the Saturnioidea but more generalized. Certain of its members resemble in some respects the Pyralididae and Gelechiidae. A cremaster is always present, usually triangular in outline and often slightly bifurcate at the distal end. The abdomen often shows three or four transverse depressions on each segment which correspond to the annulet-like rings on the body of the larva. Except in rare instances the scar of the caudal horn of the larva is visible on the dorsum of the eighth abdominal segment.

This superfamily contains a single family, the Sphingidae. For the most part the genera are easily distinguished, but there were no characters found that served to separate the genera Smerinthus and Paonias. The generic names of Dyar's list have been used as far as possible. A monograph of this family, giving tables and descriptions

for the identification of subfamilies, genera, and species, has been prepared and will be published at an early date. The following table to genera is given simply for the identification of specimens and does not indicate natural relationships. The genera may be separated as follows:

a. Spiracular furrows present on all the movable segments, that is, on abdominal segments 5–7.
  b. Maxillae with a free portion or so-called "raised tongue-case" present—the maxillary loop.
    c. Maxillary loop with its distal half recurved and touching the proximal portion, forming a prominent loop on the ventral surface of the body.....*Herse* Oken.
    cc. Maxillary loop never with the distal half recurved, the distal end touching the ventral surface of the body.
      d. Maxillary loop strongly arched from the ventral surface of the body, the greatest width of the space between the free portion of the maxilla and the ventral surface of the body always greater than the width of the maxillary loop in that region.
        e. Dorsum of body with a strongly rugose triangular area on each side of the meson of the metathorax and a similar rugose band on abdominal segments 2–8 extending over the cephalic third of the segment; lateral margins of the maxillary loop with a serrate appearance; the distal end of the loop swollen and bulb-like and at least twice the width of the remaining portion .....*Cocytius* Hübner.
        ee. Dorsum of body with a strongly elevated transverse ridge on each side of the meson on the metathorax, the abdominal segments punctate, but never rugose on the cephalic third; lateral margins of the maxillary loop never serrate in appearance; the distal end of the loop somewhat swollen but never twice the width of the remaining portion .....*Phlegethontius* Hübner.
      dd. Maxillary loop never strongly arched, but usually closely applied to the ventral surface of the body, the space between the loop and the ventral surface of the body never so great as the width of the loop in that region.
        e. Cephalic margin of abdominal segments 5–7 with one deep pocket-like furrow over each spiracle.
          f. Maxillary loop extending as far caudad as the distal ends of the prothoracic legs and occasionally beyond them. *Atreus* Grote.
          ff. Maxillary loop never extending as far caudad as the distal ends of the prothoracic legs.....*Dolba* Walker.
        ee. Cephalic margin of abdominal segments 5–7 with two furrows, the ectal furrow shallow, the ental one deep and pocket-like.

f. Spiracular furrows 5 mm. or more in transverse length and extending ventrad of the spiracle for a distance equal to the length of the spiracle.....*Chlaenogramma* Smith.

ff. Spiracular furrows always less than 5 mm. in transverse length, seldom extending ventrad of the spiracle, if so, then for a distance less than the length of the spiracle. *Sphinx* Linnaeus.

bb. Maxillae of the usual type without a maxillary loop or so-called "raised tongue-case."

c. Cephalic margin of abdominal segments 5–7 always with one deep pocket-like furrow over each spiracle, with or without a shallow ectal one.

d. With one deep pocket-like furrow over each spiracle on abdominal segments 5–7.

e. Surface of body spinose; cremaster broad and truncate, the caudo-lateral angles usually produced into sharp points; caudal abdominal segments flattened on the ventral surface, and with distinctly carinate lateral margins. *Cressonia* Grote and Robinson.

ee. Surface of body never spinose; cremaster pointed, triangular in outline, caudal abdominal segments never flattened on the ventral surface, nor with distinctly carinate lateral margins.

f. Maxillae normally reaching to the caudal margin of the wings, slightly less in some individuals; mesothoracic wings never meeting on the meson caudad of the maxillae; scar of the caudal horn never present on the dorsum of the eighth abdominal segment...*Lapara* Walker.

ff. Maxillae never more than five sevenths the length of the wings; mesothoracic wings always meeting on the meson caudad of the maxillae; scar of the caudal horn always present on the dorsum of the eighth abdominal segment. *Daremma* Grote.

dd. With one deep pocket-like ental furrow and a shallower ectal one; maxillae about two thirds the length of the wings. *Ceratomia* Harris.

cc. Cephalic margin of abdominal segments 5–7 with three or four more or less interrupted furrows over each spiracle, the surface of the furrows often punctate like the remainder of the cephalic margin.

d. Maxillae never half the length of the wings; average length of maxillae at meson 5–6 mm., sometimes 7 mm. in large specimens; dorsal cephalic margin of abdominal segments 5–7 deeply punctate, the punctures adjacent to each other, giving it a honeycombed appearance, the cephalic margin separated

from the remainder of the segment by a distinct carinate ridge. {*Smerinthus* Latreille. {*Paonias* Hübner.

dd. Maxillae half the length of the wings; average length of maxillae at meson 10 mm., sometimes exceeding this length; dorsal cephalic margin of abdominal segments 5–7 punctate, the punctures somewhat scattered and not presenting a honeycombed appearance; cephalic margin never separated from the remainder of the segment by a distinct ridge ..... *Marumba* Moore.

aa. Spiracular furrows never present on all of the movable segments.

b. Spiracular furrows present on either one or two of the movable segments.

c. Cephalic margin of abdominal segments 5 and 6 with three or four furrows over each spiracle, the furrows separated by sharply carinate ridges and extending almost to the meson on both dorsal and ventral surfaces; cremaster sparsely covered with short curved spines on the dorsal and lateral aspects. *Hemaris* Dalman.

cc. Cephalic margin of fifth abdominal segment with three or more shallow furrows over each spiracle, which never extend on to the dorsal and ventral surfaces; cremaster never with short curved spines on any portion; labrum always on the dorsal surface of the head.

d. Prothoracic femora apparent.

e. Mandibular area always elevated and usually forming prominent tubercles; cephalic margin of fifth abdominal segment with one ental furrow over each spiracle, extending for the entire width of the lateral aspect, and five or six interrupted ectal furrows with interrupted carinate ridges between; body surface dull; color light brown or coffee-color with darker markings..... *Deilephila* Ochsenheimer.

ee. Mandibular area never elevated; cephalic margin of fifth abdominal segment with either three or four entire furrows over each spiracle; body surface highly polished; color black with red markings; abdominal segments finely punctate on the cephalic half.... *Dilophonota* Burmeister.

dd. Prothoracic femora never apparent; cephalic margin of fifth abdominal segment with six or more interrupted furrows with short, more or less wavy interrupted ridges between; cephalic portion of maxillae slightly excurved and almost carinate on the meson; abdominal segments punctate over the entire length ..... *Theretra* Hübner.

bb. Spiracular furrows never present on any of the movable abdominal segments.

c. Pupae always less than two inches in length; labrum usually at the cephalic end of the body but never on the dorsal surface.

d. Pupae with a prominent tubercle on the face-parts, just mesad of each glazed eye, and a prominent tubercle on the labrum; maxillae with the proximal portion excurved and carinate on the meson .....*Deidamia* Clemens.

dd. Pupae never with prominent tubercles on the face-parts or labrum; maxillae never with the proximal portion excurved and carinate on the meson.

e. Abdominal segments 5–7 with one or more interrupted rows of spines along the cephalic margin of the segment, more prominent on the dorsal surface.....*Darapsa* Walker.

ee. Abdominal segments 5–7 never with spines along the cephalic margin of the segments.

f. Mandibular area with prominent tubercles.

g. Body surface rough, deeply punctate over the entire surface of the abdominal segments, especially segments 8–10; body tapering rapidly from the fourth abdominal segment to the long pointed cremaster; femora of prothoracic legs never apparent....*Amphion* Hübner.

gg. Body surface smooth and polished, the cephalic portion of the segment with punctures of medium size, the caudal portion finely, sparsely punctate; body tapering gradually from the fourth abdominal segment to cremaster; prothoracic femora apparent.
Lepisesia Grote.

ff. Mandibular area never elevated or with prominent tubercles.

g. Dorsum of eighth abdominal segment with a row of large deep punctures or pits along the cephalic margin; cremaster slender, never more than 2 mm. in length; body always light colored with darker markings .....*Ampelophaga* Bremer and Grey.

gg. Dorsum of eighth abdominal segment never with a row of large punctures or pits along the cephalic margin; cremaster always more than 2 mm. in length, the breadth equal to the length; body always dark brown.
Sphecodina Blanchard.

cc. Pupae always more than two inches in length; labrum either at the cephalic end or on the dorsal surface of the body.

d. Color black, often marked with red; body surface smooth and polished, with a very few small punctures on the abdominal segments; labrum at the cephalic end of the body.
Pseudosphinx Burmeister.

dd. Color uniform dark brown; body surface roughened and densely, coarsely punctate; labrum on the dorsal surface of the body, at least a distance equal to its own length away from the cephalic end of the body.....*Pholus* Hübner.

The following species were examined:
Herse cingulata Fabricius
Cocytius antaeus Drury
Phlegethontius quinquemaculata Haworth, *sexta* Johannsen
Atreus plebeia Fabricius
Dolba hylaeus Drury
Chlaenogramma jasminearum Boisduval
Sphinx kalmiae Smith and Abbot, *drupiferarum* Smith and Abbot, *gordius* Stoll, *lucitiosa* Clemens, *chersis* Hübner, *eremitus* Hübner
Cressonia juglandis Smith and Abbot
Lapara bombycoides Walker, *coniferarum* Smith and Abbot
Daremma catalpae Boisduval
Ceratomia amyntor Geyer, *undulosa* Walker
Smerinthus jamaicensis Drury, *cerysii* Kirby
Marumba modesta Harris
Hemaris diffinis Boisduval, *gracilis* Grote and Robinson, *thysbe* Fabricius
Deilephila lineata Fabricius
Dilophonota ello Linnaeus, *alope* Drury
Theretra tersa Linnaeus
Deidamia inscriptum Harris
Darapsa pholus Cramer
Amphion nessus Cramer
Lepisesia gaurae Smith and Abbot, *juanita* Strecker
Ampelophaga myron Cramer, *versicolor* Harris
Sphecodina abbotti Swainson
Pseudosphinx tetrio Linnaeus
Pholus pandorus Hübner, *achemon* Drury

Superfamily SATURNIOIDEA

The pupae of this superfamily retain none of the generalized characters found in the families previously discussed and all the sutures of the head are obliterated, even those adjacent to the proximal ends of each antenna. The body is usually heavily chitinized, and although there are always a few setae present they are rarely visible to the unaided eye. The superfamily is distinguished by the presence of broadly pectinate antennae, in the Ceratocampidae for about one third of the length, while in the Hemileucidae and Saturniidae they are broadly pectinate to the distal end, and generally have the stem of the flagellum elevated. The greatest width of each antenna is at least one fifth

of its length, often much wider, and the antennae seldom extend farther caudad than the prothoracic legs. There is a marked difference in the sexes, the antennae of the male being much broader, somewhat longer, and often meet on the meson, covering nearly all of the appendages except the wings. The legs are shorter than in most superfamilies, the prothoracic and mesothoracic legs usually either meeting or lying adjacent on the meson. The maxillae never reach the caudal margin of the wings, and their greatest length is not more than one third the length of the wings, but they are usually much shorter. The mesothoracic wings always lie adjacent on the meson and the metathoracic wings are often visible on the meson in the Saturniidae. The family Ceratocampidae has a row of broad triangular spines set on the edge of a flanged plate along both cephalic and caudal margins of the movable abdominal segments. They usually possess very long cremasters, which are always bifurcate at the distal end. The Hemileucidae have short cremasters, while there are none present in the Saturniidae and few of the genera have spines at the caudal end of the body.

A paper on this superfamily, giving tables for the identification of families, genera, and species has been prepared and the first part, "The Classification of the Pupae of the Ceratocampidae and Hemileucidae," was published in the Annals of the Entomological Society of America, Vol. 7, 1914, pp. 277–300. The manuscript for the remainder is now in the hands of the editor of the same journal. The following tables of families and genera and the descriptions, with some slight additions and corrections, are taken from the paper mentioned above. The generic names in Dyar's list are used, but the genera are not arranged to indicate natural relationships. The superfamily Saturnioidea may be divided into three families as follows:

a. Pupae with the movable segments provided with flange-like plates which prevent their being telescoped, their lateral margins distinctly tapering caudad and each segment noticeably smaller than the segment cephalad of it; wings never elevated dorsad above the surface of the body; a distinct cremaster always present; stem of the flagellum of the antenna never elevated and distinct.

b. Pupae with a distinctly bifurcate cremaster; body usually roughened with spines on the exposed surface of the thorax and abdomen; metathorax with prominent oblong tubercles on each side of the meson extending one third or more of the distance between the meson and the margin of the first pair of wings; pupae always found in the ground..... CERATOCAMPIDAE.

bb. Pupae without a distinctly bifurcate cremaster; body never roughened with spines on the exposed surface of the thorax and

abdomen; metathorax never with prominent oblong tubercles; pupae found either in cocoons or in the ground. . HEMILEUCIDAE.

aa. Pupae with the movable segments never provided with flange-like plates which prevent their being telescoped, the lateral margins approximately parallel so that the segments appear of equal size and are usually telescoped so that only the caudal margins of the segments are visible; wings prominently elevated dorsad above the level of the body, the caudal portion of the mesonotum and metanotum always depressed adjacent to the wings; a distinct cremaster rarely present; stem of the flagellum of the antenna always elevated and distinct ..... SATURNIIDAE.

Family HEMILEUCIDAE

Margins of the free segments never with a row of spines; the body surface never roughened with spines; antennae with the stem of the flagellum never distinct, the central axis never set with spines, the antennae tapering gradually from the part having the greatest width; maxillae never more than one sixth the length of the wings; proleg scars seldom prominent on abdominal segments five and six and rarely with the anal proleg scars visible; mesothoracic wings with the anal angles broadly rounded, usually at the cephalic margin of fourth abdominal segment, and usually reaching the caudal margin of the fourth abdominal segment ventrally; metathoracic wings never produced below the anal angles of the first pair of wings and never visible in ventral view; metathorax never with prominent tubercles; abdominal segments 5 to 7 with the cephalic margin produced into a thick oblique flange-like plate directed caudad; cremaster short, never bifurcate at tip.

Although not usually included with the Hemileucidae the genus Automeris is placed in this group owing to the very evident relation of the pupae to those of the genera Hemileuca and Pseudohazis. Morphologically they seem to be more nearly related to the Hemileucidae, but they are found in cocoons like the Saturniidae. Some of the members of this family pupate in the ground.

The description of this family is of necessity very incomplete owing to lack of material. According to our available knowledge of the subject the three genera may be separated as follows:

a. Cremaster bearing setae arranged in a tranverse row and spreading out fan-like..... *Pseudohazis* Grote and Robinson.

aa. Cremaster never with setae, either with curved spines or without spines or setae of any kind.

b. Cephalic part of segment above the flange-like plate either smooth or with fine longitudinal striations; pupae found in ground. *Hemileuca* Walker.

bb. Cephalic part of segment above the flange-like plate with sharp transverse ridges, deep furrows between; pupae found in cocoons ..... *Automeris* Hübner.

The following species were examined:
Pseudohazis eglanterina Boisduval
Hemileuca maia Drury, *burnsi* Watson, *olivae* Cockerell
Automeris pamina Neumoegen, *io* Fabricius, *leucana* Hübner, *incarnata* Walker

Family Ceratocampidae

Body with the margins of the free abdominal segments usually bearing a row of spines, and the exposed surface of the thorax and abdomen usually roughened with spines; antennae never broadly pectinate throughout, but broadly pectinate and almost parallel for about one half the length, then narrowed rapidly to about half the greatest width, tapering gradually to a pointed tip, the stem of the flagellum never distinct, the surface convex and the central axis of the antenna usually bearing one or two rows of small spines; maxillae never less than one fourth the length of the wings; tips of the mesothoracic tarsi meeting obliquely on the meson, never lying adjacent on the meson; proleg scars very prominent on abdominal segments five and six, the scars for the anal prolegs often very conspicuous; mesothoracic wings with the anal angles broadly rounded, usually located at the cephalic margin of the fourth abdominal segment and never reaching ventrad to the caudal margin of the fourth segment; metathoracic wings never produced below anal angle of the mesothoracic wing and never visible in ventral view; metathorax with distinct tubercles, more or less oblong in outline, on each side the meson and extending more than one third the distance from the meson to the margin of the wing; the suture between the seventh and eighth segments never deep, or with distinct crenulations on its margins; cremaster always present, usually long and bifurcate at tip. Five genera of this family have been described. One genus, Syssphinx, consisting of three species, was not available for study. The pupae of this family are always found in the ground. The remaining genera of Ceratocampidae can be separated by the following table:

a. Surface of pupa never spinose; cremaster broader than long, broadly and shallowly bifurcate, never over 2 mm. in length. *Citheronia* Hübner.

aa. Surface of pupa spinose; cremaster at least twice as long as broad, bifurcate at tip, always more than 2 mm. in length.

b. Thorax rugose with short isolated spines, abdominal segments not spinose, but bearing a row of spines along both cephalic and caudal margins of segments 1–7, the spines along the caudal margin of segments 5–7 much longer than the spines of the cephalic row .....*Basilona* Boisduval.

bb. Thorax and abdominal segments densely spinose; abdominal segments 1–7 with a row of spines along both cephalic and caudal margins, the spines in the cephalic row on abdominal segments 5–7 usually much longer than the spines in the caudal row; maxillae, measured on meson, one fourth the length of the wings.

c. Usually with prominent scattered spines on the thoracic segments, at least four times as long as those covering the segments; antennae with the central axis bearing a row of prominent spines curved caudad; if without prominent spines on the thoracic segments and antennae, then the maxillae are one third the length of the wings.

d. Eighth abdominal segment never with a prominent transverse ridge in the middle of the segment bearing a row of spines; glazed eye-piece always lighter in color than the remaining surface of the body; species always more than an inch in length .....*Adelocephala* Herrich-Schaeffer.

dd. Eighth abdominal segment always with a prominent transverse ridge in the middle of the segment bearing a row of spines; glazed eye-piece always the same color as the remaining surface of the body; species never more than an inch in length .....*Dryocampa* Harris.

cc. Without prominent scattered spines on the thoracic segments, the longest never four times the length of those covering the segments; antennae with the central axis never bearing prominent spines, the spines never curving caudad; maxillae always one fourth the length of the wings.....*Anisota* Hübner.

The following species were examined:
Citheronia regalis Fabricius
Basilona imperialis Drury
Adelocephala bicolor Harris, *bisecta* Lintner
Dryocampa rubicunda Fabricius
Anisota virginiensis Drury, *stigma* Fabricius, *senatoria* Smith and Abbot, *skinneri* Biederman, *consularis* Dyar

Family Saturniidae

The members of this family have the antennae broadly pectinate throughout, or nearly so, and the stem of the flagellum is usually distinct and raised above the level of the pectinations. The maxillae are always short, never more than one third the length of the wings, and

usually very much shorter. The tibiae and tarsi of the prothoracic legs, and the tarsi of the mesothoracic legs lie adjacent on the meson, but never meet obliquely on the meson as they do in the ceratocampids. The mesothoracic wings always have their anal angles broadly rounded and the wings always reach the caudal margin of the fourth abdominal segment on the ventral surface. The metathoracic wings are produced around the anal angles of the mesothoracic wings and usually form prominent angles on the fourth abdominal segment. The metathoracic wings always extend for at least a short distance along the caudal margin of the mesothoracic wings on the ventral surface of the body. The metathorax never has distinct oblong tubercles which are one third or more the width of the segment, such as are found in ceratocampids. The suture between the seventh and eighth abdominal segments is never deep, with distinct crenulations on its margins, and is indistinct in many species. The cremaster, if present, is very short and is never bifurcate at the distal end.

The known pupae of members of this family are found in silken cocoons. Some of these are very thick and tough, others thin and papery. Only nine genera of this family have been available for study. These may be separated by the following table:

a. Lateral margins of abdominal segments 5–7 never approximately parallel, but tapering from the cephalic margin of the fifth segment, the lateral margins usually distinctly convex; caudal end of body usually with stout curved spines.
  b. Tenth abdominal segment never flattened into a transverse plate with the caudo-lateral angles produced into short lobes.
    c. Caudal end of body without spines; body surface with slightly wavy, transverse ridges with distinct furrows between; mesothorax never with a prominent tubercle at the base of each wing. *Copaxa* Walker.
    cc. Caudal end of body with stout curved spines; body surface never with slightly wavy, transverse ridges with distinct furrows between; mesothorax with a prominent tubercle at the base of each wing.
      d. Lateral aspects of the cephalic margin of abdominal segments never with spiracular furrows; caudal end of body with an oval area set with slightly curved spines arranged in two groups and nearly all pointing outwards..... *Telea* Hübner.
      dd. Lateral aspects of the cephalic margin of abdominal segments 5–7 with spiracular furrows separated by slightly wavy carinate ridges; caudal end of body deeply rugose, with a slight concavity containing a circular group of strongly recurved spines..... *Tropaea* Hübner.

bb. Tenth abdominal segment, viewed dorsally, in the form of a transverse plate, concave on the caudal margin, the caudo-lateral angles produced into lobes; the other segments strongly concave in ventral view, with five short curved spines inserted close together in the caudo-lateral margin of each lobe.
Agapema Neumoegen and Dyar.

aa. Lateral margins of abdominal segments 5–7 always approximately parallel, the caudal end of the body never with stout curved spines.

b. Maxillae always one fourth, or less, the length of the wings, the proximal two thirds of their margins never strongly concave; mesothoracic wings with their anal angles on the cephalic margin of the fourth abdominal segment or caudad of that portion of the segment.

c. Maxillae less than one fifth the length of the wings; antennae of males with the sides tapering gradually to a pointed tip.

d. Both eye-pieces never visible in either sex; glazed eye-piece seldom visible in the females, never in the males; caudal end of abdomen never with a band of coarse setae.

e. Eye-pieces never visible in either sex; caudal end of abdomen never with spines or setae.....*Callosamia* Packard.

ee. Glazed eye-piece visible in the females; caudal end of abdomen with a few very short sharp spines.
Eupackardia Cockerell.

dd. Both eye-pieces visible in either sex; caudal end of abdomen with a transverse band of coarse setae..*Rothschildia* Grote.

cc. Maxillae never less than one fifth the length of the wings; antennae of males with the sides approximately parallel for the greater part of their length, tapering rapidly to a blunt rounded tip; a small portion of glazed eye-piece always visible in the females .....*Samia* Hübner.

bb. Maxillae always more than one fourth the length of the wings; the proximal two thirds of the lateral margins of the maxillae concave; first pair of wings with their anal angles on the third abdominal segment opposite the second pair of abdominal spiracles .....*Philosamia* Grote.

The following species were examined:

Copaxa lavendera Westwood
Telea polyphemus Cramer
Tropaea luna Linnaeus
Agapema galbina Clemens
Callosamia promethea Drury, *angulifera* Walker
Eupackardia calleta Westwood
Rothschildia orizaba Westwood, *jorulla* Westwood
Samia cecropia Linnaeus, *gloveri* Strecker, *columbia* Smith, *rubra* Behr
Philosamia cynthia Drury

Phylogeny

The characters used as a basis for determining the phylogeny of the order are primarily: (1) the number of movable segments; (2) the freedom of the appendages; (3) the number of sutures present in the head; (4) the relative length of the body segments; (5) the presence or absence of visible labial palpi and maxillary palpi; (6) the presence of exposed portions of the prothoracic femora in specialized pupae; and (7) the method of dehiscence.

In the most generalized forms there is complete freedom of motion possible between the head and thorax, and between all the segments of the thorax and abdomen with the exception of the eighth, ninth, and tenth abdominal segments, which are always fixed. As specialization proceeds, there is a gradual loss of motion; first between the head and thorax, then between the segments of the thorax, and last of all between the different segments of the abdomen. The loss of motion in the abdomen begins first at the cephalic end, but by the time that complete motion of the second segment has been lost there begins a loss of motion of the seventh segment. This takes place first in the female, and there is a large series of forms, including the superfamilies Gracilarioidea, Tortricoidea, and Aegerioidea, which retain freedom of motion in the seventh segment of the male, while there is taking place at the cephalic end of the abdomen the loss of motion of the third abdominal segment. There are, however, a few genera of Gracilarioidea which have lost freedom of motion of all the body segments and which form the most specialized end of that series. The pupae which have lost motion of all the abdominal segments except the fourth, fifth, and sixth, are those usually referred to as obtected pupae. There are few pupae more specialized than those of the superfamily Gracilarioidea which retain freedom of motion of the seventh abdominal segment in the male, but there are a few generalized forms both in the Pyralidoidea and Papilionoidea in which this is the case, as it is also in the family Epermeniidae of the Yponomeutoidea. These three superfamilies are usually considered as more specialized than the Gracilarioidea. As the number of movable segments determines the position of a superfamily in the series it is readily seen that these superfamilies must be considered as more generalized than those in which motion is lost in the seventh segment in the male. It will be remembered that a segment is spoken of as movable when motion is possible between its caudal margin and the segment caudad of it. As the appendages become soldered to the body wall on the ventral surface no motion of this part of the segment is possible if the incision between its caudal margin and the next seg-

ment is covered by the wings, therefore it can not be considered as a free segment. In many cases, however, dorsal movement of such segments is possible, which gives the segment freedom of movement in certain directions; as, for instance, in curving the caudal end of the body cephalad on the ventral surface, well illustrated in the movements of most tortricids. Such forms must be considered as more generalized than those which have lost entire motion of the segment, and thus the Pyralidoidea and Papilionoidea must occupy a lower position than the Yponomeutoidea, whose members have lost dorsal motion of the third abdominal segment, while the other two superfamilies mentioned retain it. There are certain specialized forms in other superfamilies in which motion is lost in all the body segments, notably in the family Elachistidae of the Gelechioidea and in certain genera of the family Nymphalidae in the Papilionoidea. There are also many genera in various families which retain movement in only one segment.

The appendages of the generalized pupae are entirely free from each other and from the body wall and are often considerably spread out from the surface of the body so that the pupae strongly resemble those of the Trichoptera. In these forms there is but a slight degree of chitinization in any part of the body. The appendages are gradually soldered down, however, first to each other, while all remain free from the body wall, and then there takes place a gradual soldering down of the appendages to the body wall, beginning first at the cephalic end of the abdomen. In many pupae the appendages are soldered to two, three, or four abdominal segments while the portion of the appendages caudad of these segments remains free and allows freedom of motion of the abdominal segments underneath. Such a condition exists in many genera of the Aegerioidea and Gelechioidea. The pupae with free appendages could only exist successfully in protected situations from which an easy egress was possible, and so they are only found in cocoons, or in mines in leaves and stems of plants. Pupae with any other environment lost the freedom of the appendages much more rapidly, as in the case of the Lyonetiidae and some of the Papilionoidea.

The number and arrangement of the sutures present on the head has already been discussed under the head of external morphology, pages 23 to 25. These sutures are gradually obliterated, beginning with the clypeo-labral, which is lost among very generalized pupae. The epicranial suture is one of the last to disappear, and its presence indicates the degree of specialization in many of the higher forms, as it is retained in some members of many superfamilies which are high in the series.

The fronto-clypeal suture is visible for a part of its length in most pupae, and is especially distinct for its entire length in some of the Gelechioidea; but dehiscence often showed the presence of this suture when it was impossible to locate it on the pupa. The part of this suture adjacent to the proximal end of each antenna is the last head suture to be obliterated, and it is lacking only in the Saturnioidea.

The segments of the body are more nearly of equal length in generalized than in specialized forms, especially in the abdomen. The prothorax is short in the Micropterygoidea and becomes gradually longer in the specialized superfamilies. The metathorax is long in generalized forms and nearly equals the mesothorax in length. As specialization proceeds, the mesothorax becomes longer and the metathorax much shorter, so that the comparative length of these two segments furnishes another means of determining the position of a superfamily in the series. The abdominal segments also become consolidated, first at the caudal end of the body, where they gradually become shorter than the cephalic segments. After motion is lost in the cephalic segments, they, too, gradually shorten, until the movable segments are much longer than any of the others.

The presence of visible maxillary and labial palpi also furnishes an easy means for the identification of generalized forms. The labial palpi are retained throughout the series, but are gradually overlaid and concealed by the maxillae. The presence or absence of visible labial palpi, however, indicates the degree to which specialization has proceeded along a given line. Labial palpi are visible to some extent in some members of all superfamilies except the Saturnioidea. The maxillary palpi are usually the first to disappear, but these palpi are often present in the pupa, when lacking in the imago. The maxillary palpi in generalized forms reach the proximo-lateral angles of the maxillae, but gradually decrease in length until they are visible only as a small triangular area caudad of the sculptured eye-piece.

When the appendages are free their position is considerably laterad of that which they gradually assume as they become soldered to each other. The legs are folded in such a way that in generalized forms almost the entire femur of the prothoracic leg is exposed. Later the tibia and tarsus of this leg are folded so that their position is nearer the meson than formerly and the femur is entirely concealed. The presence of an exposed portion of the prothoracic femur is a generalized condition which is retained by forms exceedingly specialized in other respects, and is found in some genera of Sphingidae.

As to the method of dehiscence, there are several things to be noted, although all too little is known of this interesting phase of pupal

life. There is a tendency for the generalized forms to emerge from the mine, cocoon, burrow, or other place of protection, as a pupa, and consequently the body is provided with some structure which assists in its progress. The appendages and body segments are usually separated from each other at dehiscence and the body splits along the median line of the vertex and thoracic segments, the vertex carrying the sculptured eye-pieces with it. The front, with the antennae, is completely separated from the rest of the head parts in some forms, by a splitting along the epicranial suture on the dorsum, and along the fronto-clypeal suture on the ventral surface. When the fronto-clypeal suture is not entire it usually splits for a part of its length, thus allowing it to be considerably elevated. In specialized forms it is usually the imago which emerges, the pupal skin being left behind in the cocoon or other place of protection. The appendages and body segments remain firmly soldered together and the imago escapes through the opening made by the splitting of the vertex, when present, the prothorax, and the mesothorax; or, if this is not sufficient, an irregular opening which does not follow the line of any suture is made in the cephalic end of the body. In these forms the eye-pieces remain attached to the other face-parts.

The phylogeny of any group is usually determined by the development of a single character. Many workers have used the venation of the wings to arrange a series of genera or species in phylogenetic order. Others have used the genitalia, or the arrangement of setae. The pupae present many and varied characters which may be used to arrange such a series. In this investigation a series was arranged for each of the characters previously mentioned and the results of these series were combined. These characters have the advantage over those used by previous authors in that they comprise practically all of the important structures of the body and are all present in the same individual. It is quite probable that other characters might be used to indicate the development of the order, such as the number and arrangement of the genital apertures, the form of the spiracles, and the arrangement of setae, none of which have been investigated sufficiently to admit of their use in this paper.

Acknowledgments

The subject for this investigation was suggested by Professor A. D. MacGillivray in September, 1912. Since that time many species of Lepidoptera have been collected, both in the larval and pupal stage, and reared to maturity. The Graduate School of the University of

Illinois has made liberal appropriations for the purchase of material, and a large series of named pupae has been obtained from the following sources: the American Entomological Company, Ward's Natural Science Establishment, the Kny-Scheerer Company, the New England Entomological Exchange, the New Jersey Entomological Company, and from Mr. Wm. Beutenmüller, A. H. Manee, of Southern Pines, N. C., E. J. Oslar, of Denver, Colo., and Miss Annette F. Braun, of Cincinnati, Ohio. Dr. L. O. Howard, Chief of the Bureau of Entomology of the U. S. Department of Agriculture, Mr. August Busck, of the U. S. National Museum, and Dr. Wm. Barnes, of Decatur, Ill., have furnished a number of rare species which contributed in no small measure to the progress of the investigation. The collections of the Illinois State Laboratory of Natural History have been freely available, and for this courtesy Professor S. A. Forbes deserves our hearty thanks as well as his assistants, Mr. J. R. Malloch and Mr. C. A. Hart. Dr. T. H. McDunnough, of Decatur, Ill., and Miss A. F. Braun have assisted in the identification of bred material, thus making available many species that otherwise could not have been used. The collections furnished by Miss Braun and Mr. Beutenmüller deserve especial mention. Miss Braun collected, bred, and determined more than one hundred species of the so-called Microlopidoptera which really formed the working basis for this part of the investigation. Most of the work done on the Sphingidae has been from specimens furnished by Mr. Beutenmüller, who has collected a large series of forms. Mr. Samuel Henshaw, of the Museum of Comparative Zoology at Harvard, very kindly loaned a large series of Papilionoidea, most of which were collected by Dr. S. H. Scudder and described in his "Butterflies of the Northern United States and Canada." Professor J. G. Needham, of the Department of Entomology at Cornell University, also loaned a large number of species from the collections of that University, which were especially valuable and could not be obtained elsewhere.

It would be impossible in this brief space to enumerate the many ways in which Professor MacGillivray has assisted in the preparation of this paper. His interest in the work has been unfailing, and whatever of value it may contain is due to his inspiration, encouragement, and helpful criticism.

Bibliography

Chapman, T. A.

'93. Some neglected points in the pupae of the heterocerous Lepidoptera. Trans. Ent. Soc. London, 1893: 97–119.

'93. On a lepidopterous pupa (Micropteryx purpurella) with functionally active mandibles. Trans. Ent. Soc. London, 1893: 255–265.

'94. Some notes on the Microlepidoptera whose larvae are external feeders. Trans. Ent. Soc. London, 1894: 335–350.

'96. Notes on pupae—Orneodes, Epermenia, Chrysocorys and Pterophorus. Trans. Ent. Soc. London, 1896: 129–147.

Jackson, W. Hatchett.

'91. Morphology of the Lepidoptera. Trans. Linn. Soc. London, Zool., Ser. 2, Vol. 5.

Packard, A. S.

'95. Attempt at a new classification of the Lepidoptera. Monograph of the Bombycine moths of America north of Mexico, Part I. Memoirs of the National Academy of Sciences, 7: 56–83.

Poulton, E. B.

'91. The external morphology of the lepidopterous pupa. Trans. Linn. Soc. London, Zool., Ser. 2, 5: 245–263.

Scudder, S. H.

'89. The butterflies of the Eastern United States and Canada. 3 vols.

Tutt, J. W.

'00. A natural history of the British Lepidoptera, 2: 38–100.

PLATES

The following plates show in outline the principal structures of pupae of many of the families discussed in this paper. No attempt has been made to show all of the setae, spines, or tubercles which may occur, but only those which are most important and are of taxonomic value.

The following abbreviations have been used:

a,	antennae
a1–a10,	abdominal segments 1–10
af,	alar furrow
ao,	anal opening
ar,	anal rise
at,	invaginations for the anterior arms of the tentorium
cl,	clypeus
cls,	clypeo-labral suture
cdm,	caudal margin of an abdominal segment
cm,	cephalic margin of an abdominal segment
cr,	cremaster
cs,	cremastral setae
cx1,	coxa of the prothoracic leg
cx2,	coxa of the mesothoracic leg
cx3,	coxa of the metathoracic leg
dlt,	dorso-lateral row of tubercles
dmt,	dorso-mesal row of tubercles
dst,	dorso-spiracular row of tubercles
es,	epicranial suture
f,	front
fcs,	fronto-clypeal suture
f1	femur of the prothoracic leg
f2,	femur of the mesothoracic leg
fp,	flanged plate
g,	genae
ge,	glazed eye-piece
go,	genital opening
lb,	labrum
l_1,	prothoracic leg
l_2,	mesothoracic leg
l_3,	metathoracic leg
lp,	labial palpi
md,	mandibles
mp,	maxillary palpus
ms,	mesothorax
msp,	mesothoracic spiracle
mt,	metathorax
mx,	maxilla
p,	prothorax
pf,	pilifer
psc,	proleg scar
s,	spiracle
se,	sculptured eye-piece
sf,	spiracular furrow
t,	tegulae
ts,	tubercle scar
v,	vertex
vst,	ventro-spiracular row of tubercles
w1,	mesothoracic wing
w2,	metathoracic wing

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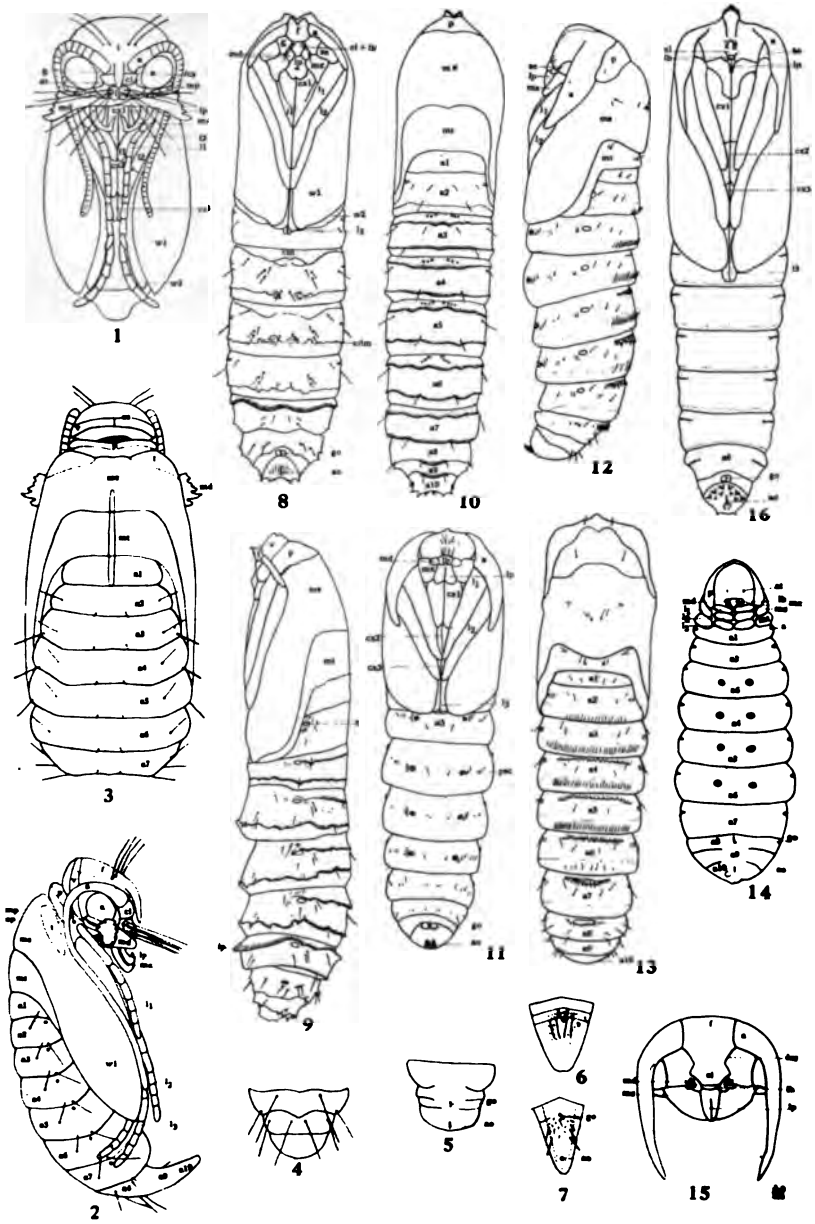

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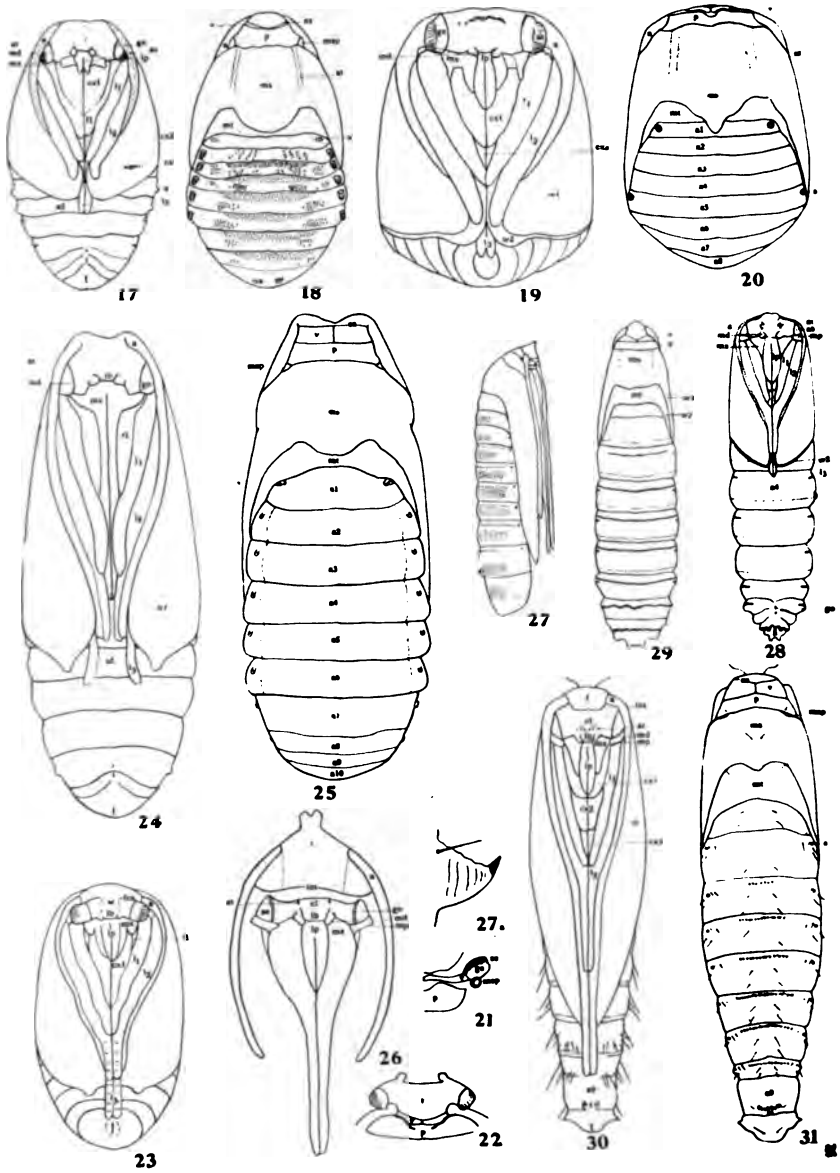

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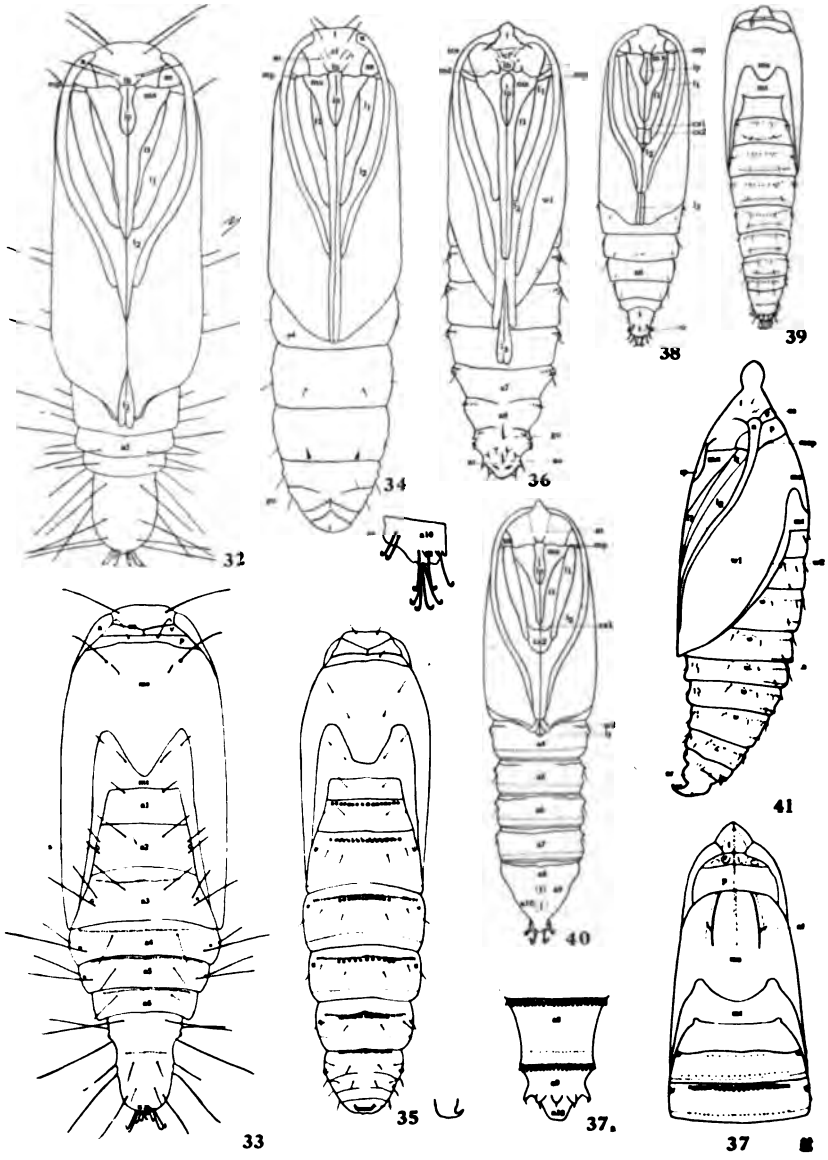

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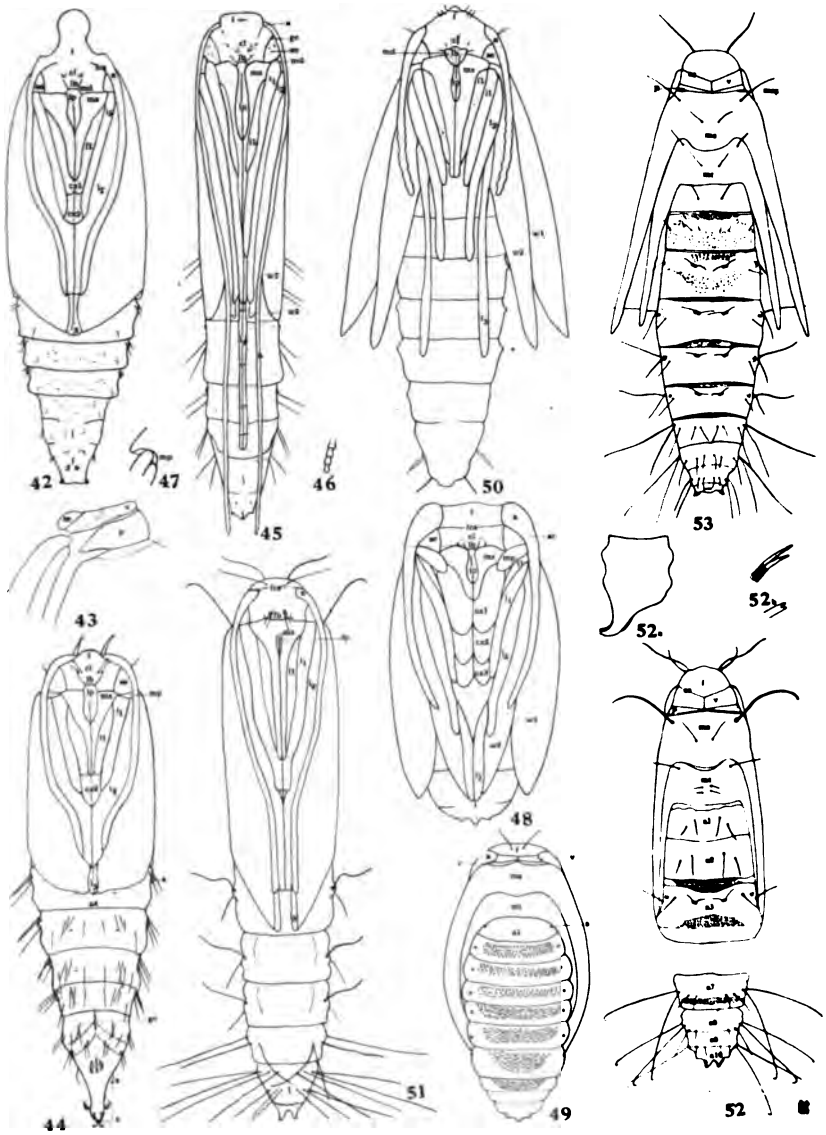

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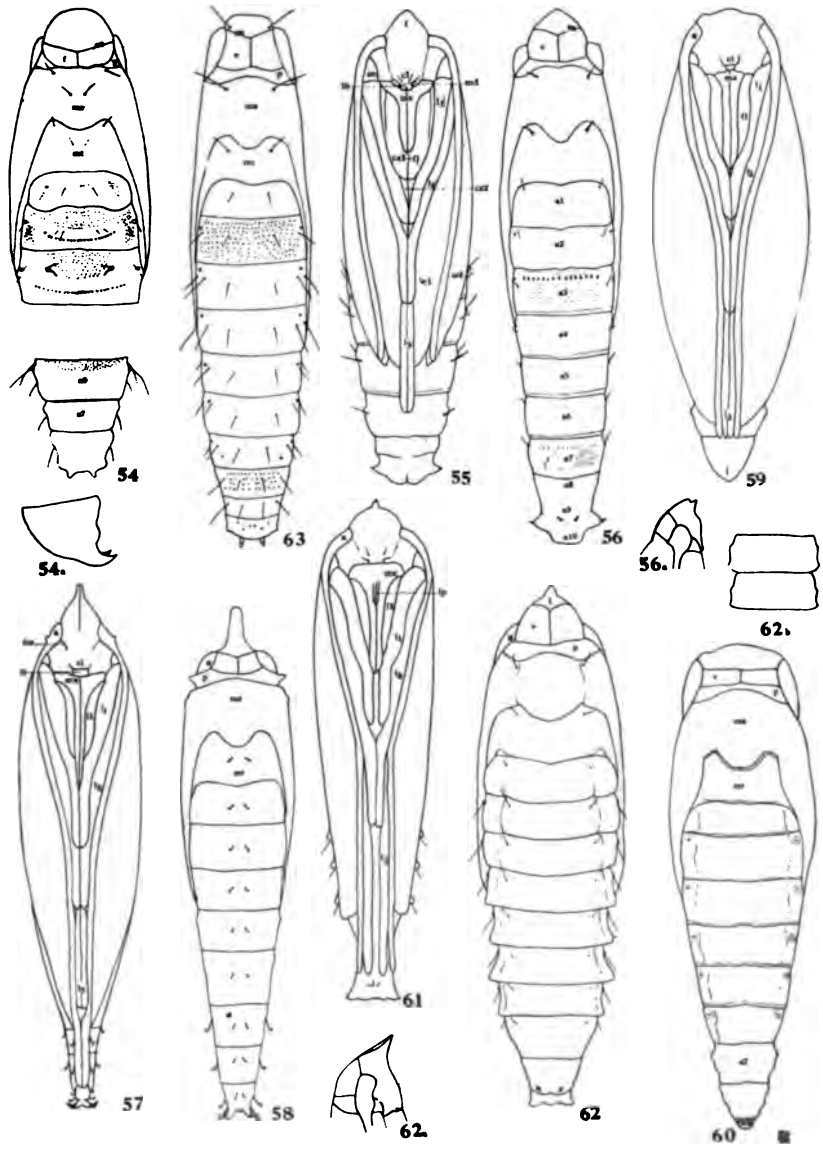

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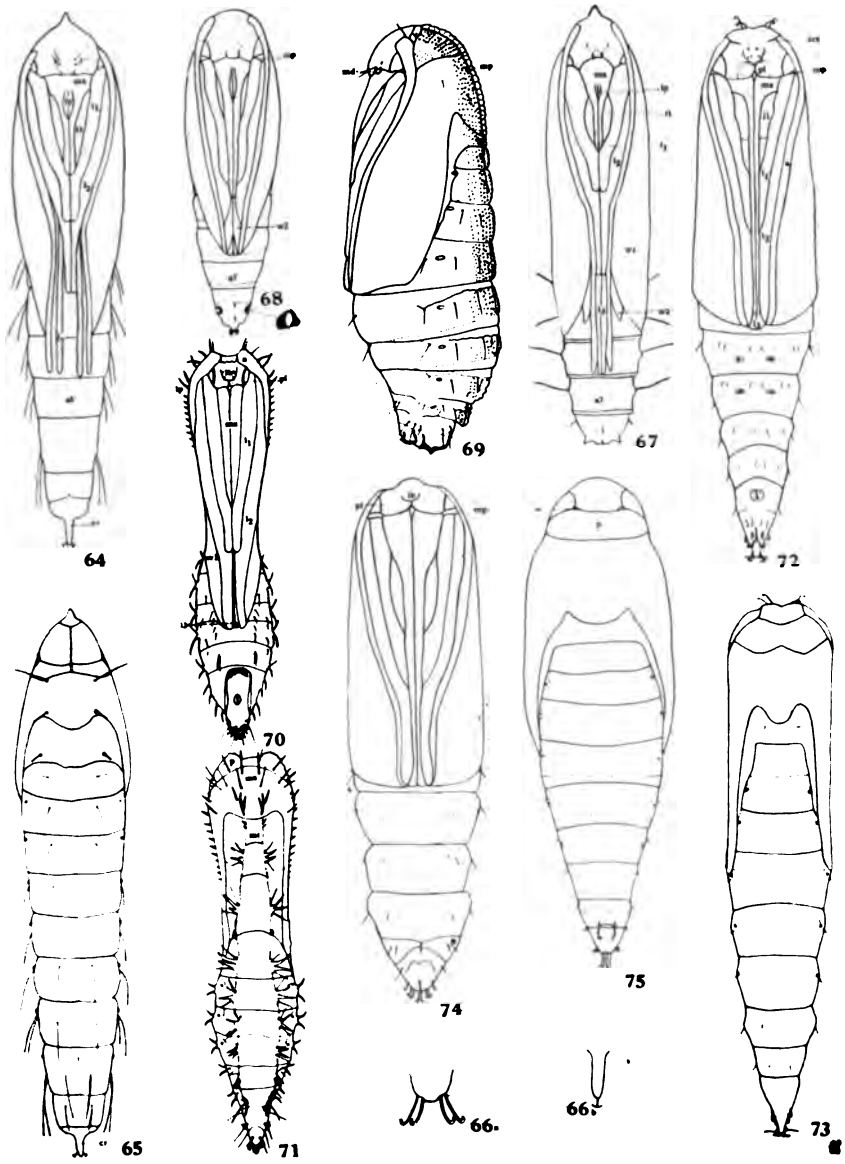

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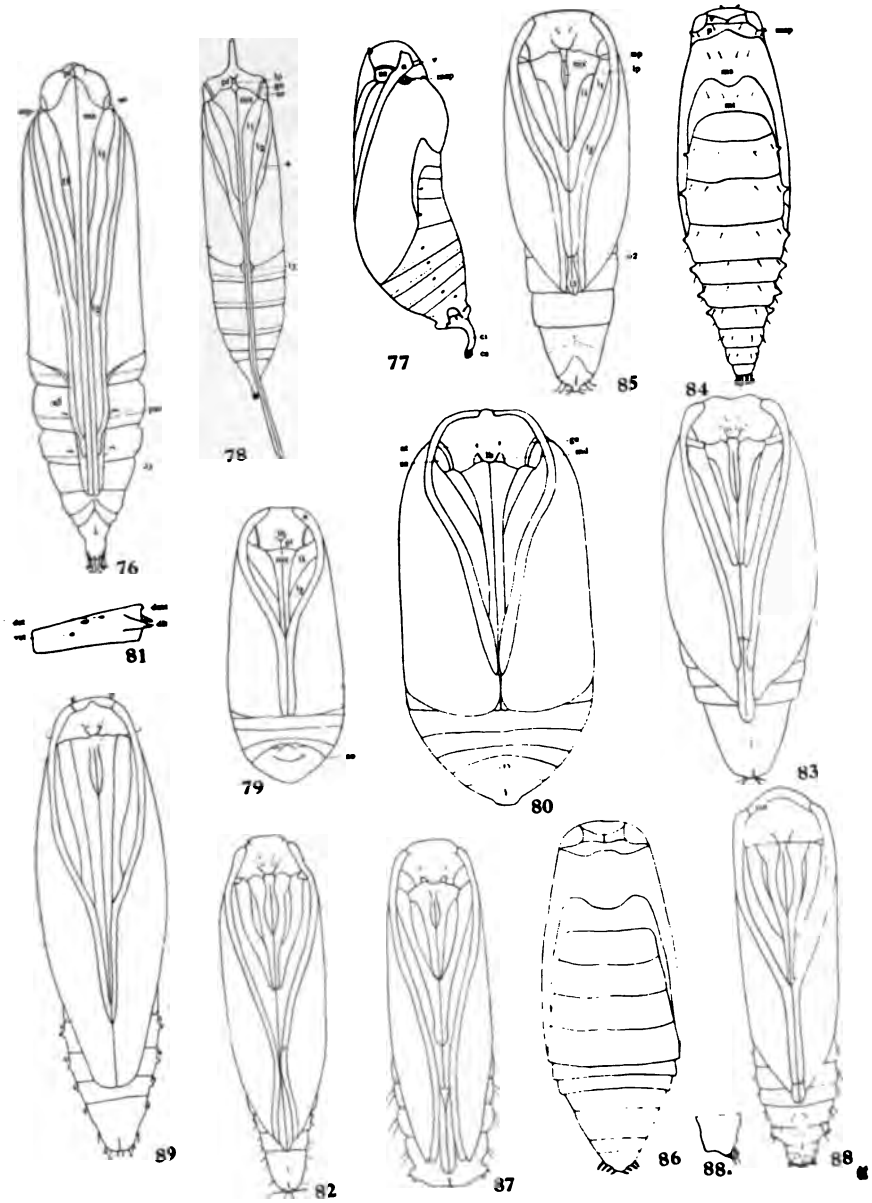

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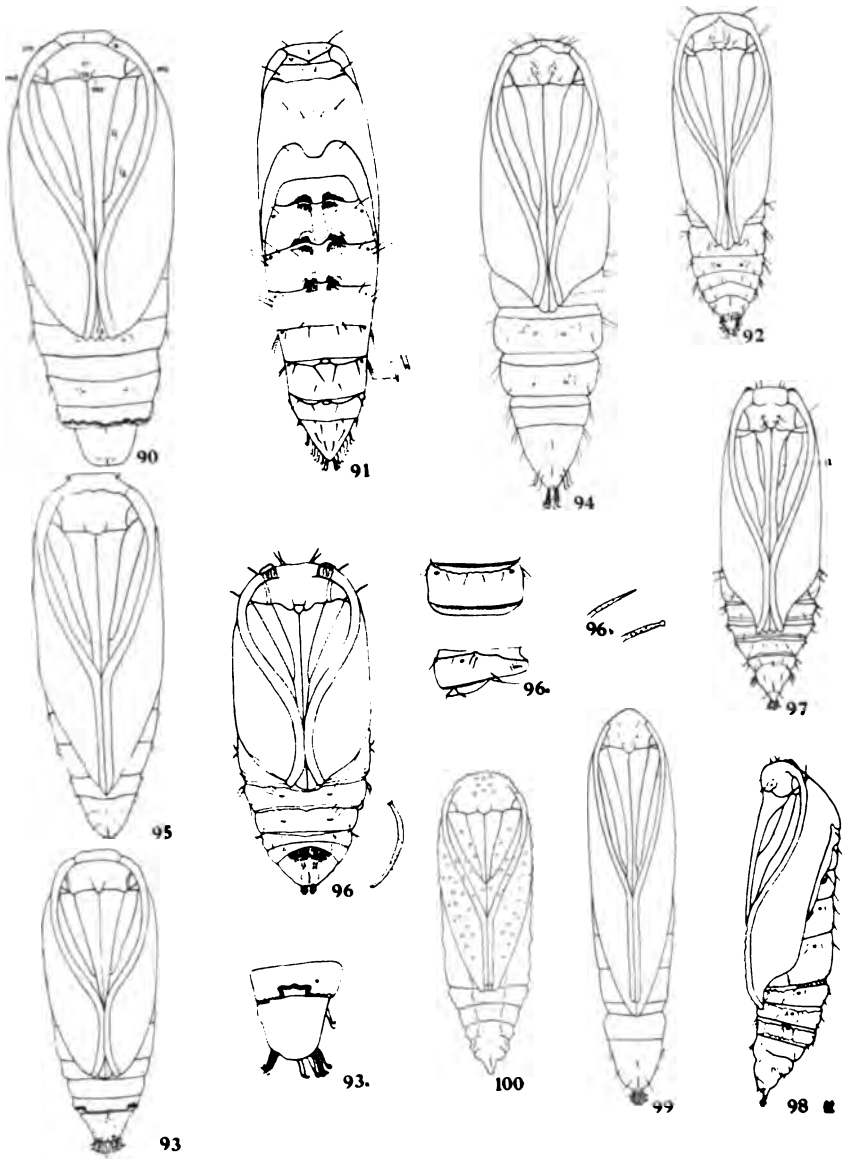

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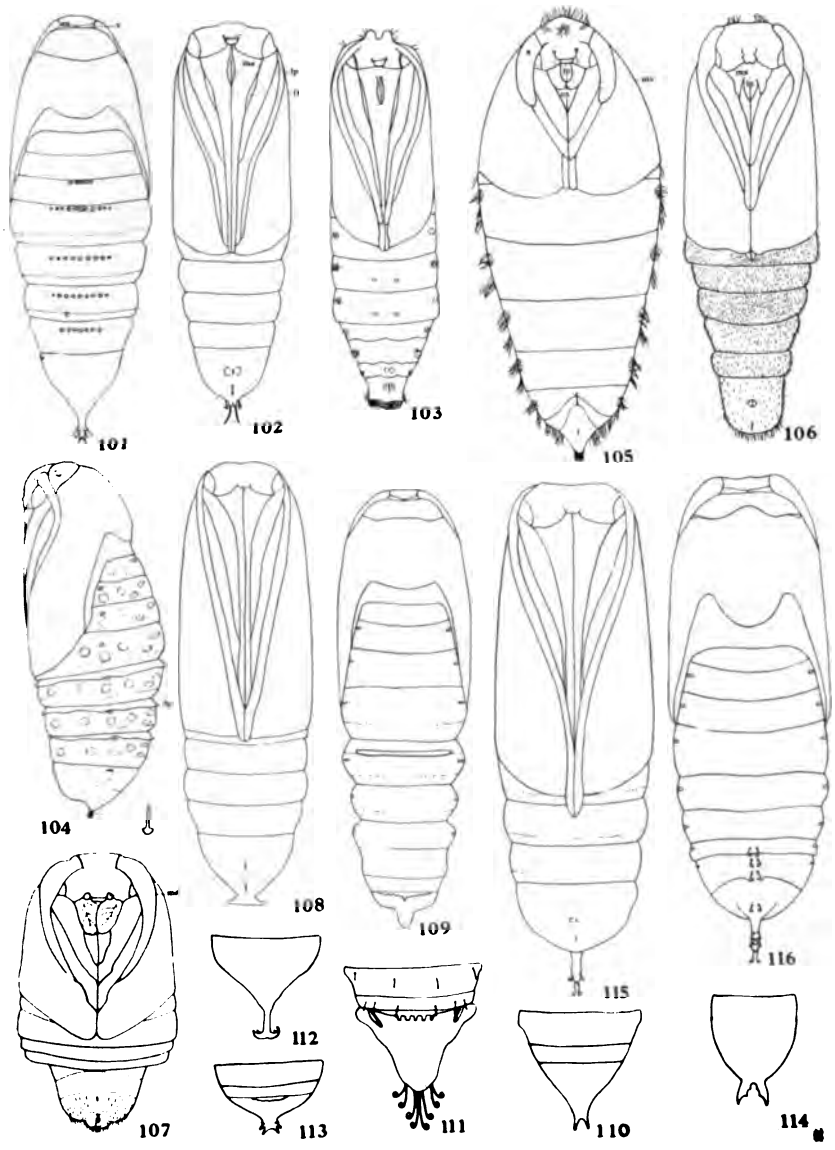

VITA

The writer was born at Kempt Shore, Nova Scotia, and educated in the public schools of that province, graduating from the Provincial Normal School in 1902. For three years she held a position in one of the units of Sir William MacDonald's consolidated school garden system and then entered Cornell University, graduating in 1908 with the degree of Bachelor of Science in Agriculture. The next two years were spent as teacher of agriculture in the High School at Hampton, Virginia, and as supervisor of nature study and school gardening in the public schools of that city. A similar position was held in the public schools at Gary, Indiana, until 1912. The summers of 1909–1911 were spent as instructor in agriculture and nature study in the State Normal Institute at Emory, Virginia. From September, 1912, until the present time the writer has been a graduate student at the University of Illinois, as scholar in Entomology during the year 1912-1913 and as fellow in 1914-1915. She received the degree of Master of Science in 1913.

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